Eng

MORRISON'S

PRACTICAL ENGINEER

AND

MECHANICS' GUIDE,

CONTAINING

A GLANCE AT THE EARLY HISTORY OF STEAM; ITS APPLICATION TO PUMPING; ITS LATER USE FOR RAILROADS AND STEAMBOATS; ITS MORE EXTENSIVE USE FOR GENERAL MACHINERY.

THE SETTING AND MANAGEMENT OF BOILERS:

THE MODERN STEAM ENGINE; HOW IT SHOULD BE MANAGED. DESCRIPTION AND APPLICATION OF THE INDICATOR. ILLUSTRATIONS SHOWING THE ADVANTAGE OF THE ENGINE BEING IN THE BEST POSSIBLE CONDITION FOR DUTY.

TABLES AND RULES

FOR DEMONSTRATING THE ACTUAL WORKING OF THE ENGINE, WITH METHODS OF CORRECTING THE DEFECTS. RULES FOR CALCULATIONS. TABLES FOR VARIOUS CALCULATIONS RELATING TO METALS AND OTHER MATERIALS. TESTS AND METHODS OF WORKING METALS. USEFUL PRACTICAL INFORMATION, RECEIPTS, ETC.

BY WILLIAM A. MORRISON,

MEMBER OF AMERICAN SOCIETY OF MECHANICAL ENGINEERS

SECOND EDITION--REVISED AND IMPROVED.

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PREFACE.

In offering the second edition of this book to the Public, especially to that class known as Steam Engineers, the author desires to lay before them such facts and general information as he has gained by an experience of many years in the business. In doing this he wishes to help to elevate, and make more competent a large class, which in this age of Steam, has become an important element in the world's advancement, and upon which largely depends the safety of transportation of passengers and freight throughout the world. Also, in the busy hives of industry everywhere, much depends upon the economical production, care, and useful application of *Steam*.

In presenting this book, it is not claimed that the rules, tables and formulas for calculation are entirely new, the author is largely indebted to such works as Haswell, Winslow, Briggs, Bacon and Howard, for which he makes due acknowledgement.

But seeing from many years intercourse with the class of men herein named, the great need of a practical treatise on Steam Engineering, presented in such a form as would be readily understood by those directly interested, and especially beneficial to young engineers, he cannot but hope this work will reach the class for whom it is intended, and be found interesting and helpful to them.

Slight changes have been made in a few instances, and the page on electric lighting has been rewritten to meet the greatly reduced cost of electric lighting machinery, materials, and supplies. The book as improved, is submitted to the public with thanks by the author for their appreciation of the first edition.

WM. A. MORRISON,

~~P. O. Box 373, Lowell~~, MASS.

DEFINITIONS

OF THE SIGNS USED IN THE FOLLOWING WORK.

$=$ *Equal to.* The sign of equality; as 16 oz.$=$1 lb.

$+$ *Plus*, or *More.* The sign of addition; as $8+12=20$.

$-$ *Minus*, or *Less.* The sign of subtraction; as $12-8=4$.

$\times$ *Multiplied by.* The sign of multiplication; as $12\times8=96$.

$\div$ *Divided by.* The sign of division; as $12\div4=3$.

$\backsim$ *Difference between the given numbers or quantities*; thus, $12\backsim8$, or $8\backsim12$, shows that the less number is to be subtracted from the greater, and the difference, or remainder, only, is to be used, so, too, *height*$\backsim$*breadth* shows that the difference between the height and breadth is to be taken.

: :: : *Proportion*; as 2 : 4 :: 3 : 6; that is, as 2 *is to* 4, *so is* 3 *to* 6.

$\sqrt{}$ *Sign of the square root;* prefixed to any number indicates that the square root of that number is to be taken, or employed; as $\sqrt{64}=8$.

$\sqrt[3]{}$ *Sign of the cube root;* and indicates that the cube root of the number to which it is prefixed is to be employed, instead of the number itself; as $\sqrt[3]{64}=4$.

^{2} *To be squared, or the square of;* shows that the square of the number to which it is affixed is the quantity to be employed; as $12^2\div6=24$; that is, that the square of 12, or $144\div6=24$.

^{3} Indicates that the cube of the number to which it is subjoined is to be used ; as $4^3=64$.

. *Decimal point*, or *separatrix.*

$\overline{}$ *Vinculum.* Signifies that the two or more sums, over which it is drawn, are to be taken together, or collectively, as forming one sum, thus, $\overline{4+6}\times4=40$; whereas, without the vinculum, $4+6\times4=28$; also $12-\overline{2\times3+4}=2$; and $\sqrt{\overline{5^2-3^2}}=4$. So, also, $\sqrt{(5^2-3^2)}=4$.

% *Sign of per cent.* Signifies so much per cent; as \$1.00 at 6%, or 6% of \$1.00=6 cents.

° ′ ″ Signifies degrees, minutes and seconds.

A GLANCE AT THE HISTORY OF STEAM.

Steam has been used as a motive power for upwards of two hundred years, but not until James Watt, near the latter part of the last century, made a successful application of it for driving machinery and pumping water, and later Robert Fulton and Oliver Evans applied it to the steamboat, and George Stephenson to the locomotive, was it considered a success. Although the early efforts of Watt were very crude, yet his principles of the steam engine are the base of the advanced successful steam engine of to-day. The same ideas of expansion, condensation and regulation by automatic cut-off, occupied his thoughts (although he did not make a success of the last), and were the controlling principle in all his plans and efforts.

From the cumbersome mass of the single acting steam cylinder, the ponderous beam and counter balance weight, and later the enormous fly wheel, have come the beautiful, symmetrical, compact, strong mechanism composing the structure of the engine of to-day; and instead of a machine requiring the consumption of 10 lbs. or more coal per hour, to produce one horse power, we have the modern high speed, high pressure, compound, condensing, jacketed cylinder, automatic cut-off engine, capable of running with best form of boilers, with 1¾ lbs. of coal per horse power, per hour.

THE SETTING AND CARE OF BOILERS.

As so much depends on the structure, setting and care of boilers, to produce favorable results, special attention is given to those points.

BOILERS.

The horse power of the boilers should be 20 per cent. greater than the maximum power of the engine, and when steam is used for heating and other purposes, a liberal allowance should be made. With the indicator we may determine very closely the performance of the engine; with the boiler it is very uncertain and vague what may be going on in the furnace, and inside the shell we cannot so easily determine. The engineer must depend largely upon his judgment. Close observation may, however, teach much. The Horizontal Return Tubular boiler as the kind most generally used, is referred to here. The mistake is frequently made of crowding the grate up too close to the shell. A vessel of water when held close to the flame of a lamp, will speedily be covered with smoke, and take a longer time to boil than if kept clear of the flame. Therefore, a plenty of room should be allowed for the complete combustion of the products of the fuel, and to prevent a deposit of unconsumed carbon on the relatively cooler surfaces of the boiler. The grates, therefore, should not be less than 25 inches to 30 inches below the shell. If the boiler front will not admit of it they may be pitched back somewhat, but not to exceed 1½ inches to the foot. Have grates of such construction as will give abundant air space.

The width of the furnace inside should be at least 6 inches more than the diameter of the boiler, and of sufficient depth to allow ½ of one square foot of grate surface to each horse power of the boiler. The bridge wall should not be over 12 inches high, and for one-half the distance between the bridge wall and back end, carry a flat incline to within 10 inches of the shell of the boiler and thence run horizontal to the back. Do not attempt to conform to the curve of the boiler.

It is a disadvantage to return the smoke and gases after passing the tubes over the top of the boiler. The temperature of the steam inside of the boiler at 80 lbs. pressure is about 320°. Any reduction of the gases below that temperature, would actually cool the boiler. Not infrequently the temperature in the flue after leaving the tubes, may be less than 300° Fahrenheit, which would act as a wet blanket upon the boiler, and would result in loss. Any apparatus placed in the flue for the purpose of utilizing the heat, in heating feed water, must result in loss, unless the flue is unnecessarily large. A boiler correctly proportioned should exhaust the heat from its gases down to about 400° temperature by the time they are through the tubes, and after that they should be got into the chimney as quickly as possible to assist the draft. The height of the chimney should be 26 times the diameter of the flue. This rule may be varied somewhat to suit different localities. Boilers should not be too long. The best experience shows that the length of tubes should be from 45 to 50 times their diameter. The steam space or length of a boiler containing 2½ in. tubes, should not be over 10 ft. long; 3 in, tubes, 12 ft. long; 4 in. tubes, 16 ft. long; and this without reference to the diameter of the shell, add to this length whatever may be required for the flue, or breeching, as usually termed. Keep the shell of the boiler as hot as possible on the outside; do not close the side walls too low down upon the boiler; let the hot gases remain dead as high as possible on the sides and even over the top (except immediately over the grate surface), if convenient to arch it over, having the ends properly protected and enclosed. The boiler is thus kept at a more equal heat, giving dryer steam and adding to its long service, by not causing so much unequal expansion and contraction. Have all exposed surfaces of pipes and boilers well protected with non-heat-conducting material. These points are not claimed as original, but on the contrary they are borrowed from the best engineering practice in the country.

The economy or evaporating capacity of the boilers may be expressed in the number of pounds of water evaporated into dry steam with one pound of coal.

With good hard or soft coal, a tubular boiler set as above, a good draft, and skillful firing, will evaporate 9 to 10 lbs. of water with 1 lb. of coal. The average result is at least 35 per cent. below this.

With these data and a knowledge of the economy of the engine, a close approximation of the fuel consumption may be had, Tubes should not be nearer than 3 in. to the shell, allow sufficient space between for circulation. Have room at the bottom for large manholes to admit of examinations and thorough cleaning. Tubes near the bottom of the shell are of little value for heating

To determine the horse power of a boiler, add together all the heating surface, including the tubes, in square feet and divide by 12, which will give the relative horse power. A boiler for first-class automatic engine, should be large enough to evaporate 30 lbs. of water to each horse power of engine per hour; plain slide valve 40 per cent. more to be of sufficient power.

There are several practical points in reference to the management of boilers which are too much overlooked. One of the most important is a

properly made fusible plug and put into the boiler in the right place. It should be made of the best steam metal, filled with U. S. standard Banca tin. For a horizontal tubular boiler, it should be placed at the highest point of fire contact at the back end, above the tubes; for an upright tubular boiler, in the crown sheet of the fire box; in a locomotive boiler, in the back corner of crown sheet in fire box, or at back end. It should be examined internally and externally as often as once a year, and renewed if necessary, but should not be used more than two years without renewal. The safety valve should be lifted once a week and examined as to condition. Observe if the weight is placed right. The boilers should be blown off under pressure twice in the 24 hours, in the morning before starting the engine, and after stopping, or during the night. A surface blow-off is a good thing when the water is bad and much foreign matter is held in solution, particularly if much oil is used in the steam cylinder. Blow out the tubes with steam jet once a week and use a suitable brush or scraper often. Do not allow bunches of oil and dirt to collect on the tubes or shell. Never pump cold water into the boilers if it can be avoided; it is contrary to good engineering and exceedingly injurious to the boiler. Keep the feed water as near the boiling point as possible with a suitable heater, or other convenient methods. As a general thing it is not advisable to go above it. Run your boilers as equal as possible with the water about 6 in. above the tubes. Keep the fires thin (about four inches), and even on the surface. Circumstances may vary these conditions, which will require much good judgment. Examine carefully as often as possible the internal condition of your boilers. See that they are kept clean, and any necessary repairs required have attended to at once. Engineers that attend strictly to these things, save themselves a vast amount of time and anxiety and promote the interests of their employers, and, last but not least, add security to the whole community.

THE STEAM ENGINE.

In regard to the Stationary Steam Engine, there is a great variety of opinion among builders as to the form of construction, style of bed, dimensions and positions of bearings, form of valves, and methods of operating them, whether the engine shall be long or short stroke, high, low or medium speed.

But all are agreed upon these points: that the steam must be hot and dry, that it must come into the cylinder unobstructed, that it must be high pressure to get its expansive effects, and that it must do its work quickly to prevent condensation. Until George H. Corliss introduced his improvements about the year 1848, these points had not been reached, and many of them were unknown. When he made a successful application of the automatic cut-off to the main valve, as operated and controlled by the governor, so as to produce a perfectly uniform speed, and use at each stroke only as much steam as was required to do the work, and maintain the speed, he made a mark upon the steam engine which will not be obliterated so long as the steam engine is known. The result was that instead of using 6 lbs. of coal per horse power per hour, as heretofore, with best constructed engines, now only 3 lbs. were used.

In the successful working of the engine the most important point, is to have the valves properly *set*. This matter is not understood sufficiently by those having them in charge. Both employers and employed seem to think that if the engine continues to run, and does the work reasonably well,

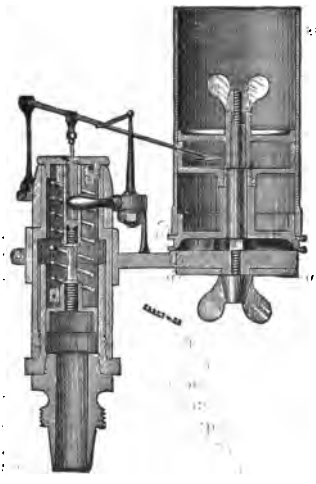
that is about all that is required. This is far from the truth. The only correct method to determine the actual condition of the engine is by the use of the indicator. How many who call themselves *good engineers* know anything about the practical working or the value of this important instrument?

THE INDICATOR AND ITS USES.

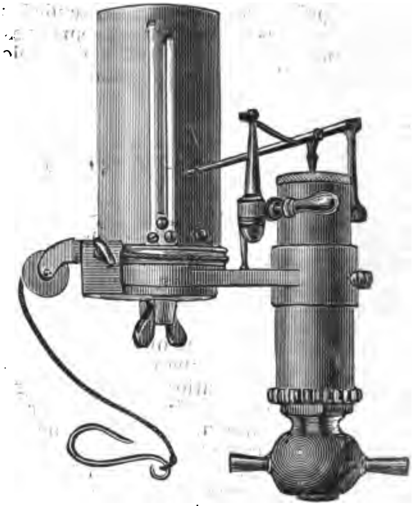
It is my purpose in this work to treat of this subject in such a way as to make it plain to the average engineer, and, if he has sufficient intellegence, to gain a fair knowledge of the simple rules of arithmetic (if he has not that already), by which he can make use of the Indicator and put his valves in proper position for *effective* service, and make the necessary calculations to determine the power of his engine, under all conditions. If he cannot do this, he certainly is not competent, to take entire charge of machinery of so much importance.

For the purpose of a full understanding of the subject, a cut of the Thompson Improved Indicator is here introduced, with full description; also a series of diagrams, and diagrams from the author's own practice, fully illustrating the difference between an engine in *good* condition and those struggling to do their work under serious difficulties.

INSIDE VIEW.



OUTSIDE VIEW.



General Directions for Using the Thompson Indicator.

Make the connections as short and large as the circumstances will permit, never less than a half-inch pipe with three-fourths inch bends. If side pipe and three-way cock are to be used, open up the cylinder for three-fourths inch pipe (one inch is better) with one inch bends. See that the three way cock has full capacity so as not to choke the Indicator. Square up the ends of the pipes with the file, ream carefully so as to give a smooth,

even flow of steam and prevent the danger of small particles of the burr blowing off and injuring the Indicator and engine. Blow the pipes out thoroughly before connecting the Indicator. See that it stands vertical and firm; no motion or jar is admissible. Wind some non-conductor (an old woolen shirt, if nothing better offers) around the pipe to prevent condensation.

Keep the engine room at an even temperature, and as high as you can bear to work in comfortably while taking cards.

Now about the drum motion.

Whatever device you use for reducing motions, avoid carrying pulleys as much as possible. You must have straight leads; angular vibrations of drum-line are never to be permitted.

If using the pantograph (which is the most convenient, reliable and durable instrument now in use), get hold of the cross-head where most convenient,—at suitable distance to clear at all parts of stroke, and in line with the post. Place the post at mid-stroke of connections, and at such a distance that it will not shut too close; it must be firm and at such a height that the pantograph-button will be in line with the Indicator leaders. Drop on the pantograph, and try it; if it runs smoothly, and the post does not vibrate or tremble, all right; if it does, find the cause, and remedy it, or your work will be worthless.

Having succeeded in accomplishing so much, now for a card.

Take the Indicator apart, clean and oil it; try every part separately; see if it works smoothly; if so, put it together without spring; lift the pencil lever, and let it fall; if perfectly free, put in the spring, and connect; give it steam, but do not attempt to take a card until it blows dry steam through the relief. (The least particle of water will spoil the work.) Now take cards, but do not close the oil-cup from the steam, as advised by many writers on the Indicator; if you do, you will find you are indicating one engine and running another, especially if the engine be of the Corliss pattern. The valves will stick and jump in all cases more or less, according to pattern of engine and pressure of steam; whereas if lubricated they will run smoothly and evenly. If the oil gums the Indicator, it will soon let you know; so take it off, clean it, and try again.

In measuring cards the planimeter is indispensable. You can approximate the area by the old method, but in all angles where a curved line divides the squares, it becomes more or less a matter of guess-work; while the planimeter, if properly handled, is positively correct to .01 of an inch. As to reading cards, there can be no directions given which amount to anything; common sense and careful reasoning will find the cause that produced the effect. The cause once found will suggest its own remedy.—[American Steam Gauge Company.

AMSLER'S POLAR PLANIMETER.

There are several other instruments which are used as accessories to the Indicator, and which greatly facilitate the use of the instrument, one of which is Amsler's Polar Planimeter, as shown by the accompanying cut, for measuring the area of indicator diagrams. By using this instrument the whole work of measuring a diagram can be done in one minute.

Engineers who have many indicator cards to work up cannot afford to be without a Planimeter.

Directions for Using the Instrument.

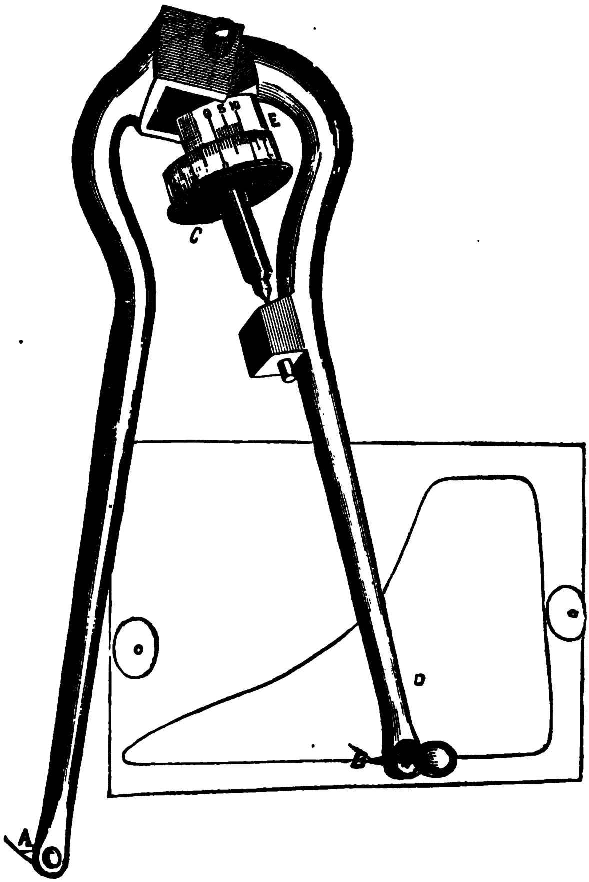
Press the point A slightly into the paper, not clear through, in such position that the tracer B will follow the desired line without bringing the

roller C against any projection. The roller must move on a continuous flat surface.

It is also well to fasten the diagram to a drawing-board, or some other flat surface, by means of pins or springs, to prevent it from slipping.

Mark a starting point at any point on the outline of diagram D, set the tracer on that point, and place zero on the roller so it exactly coincides with zero on the vernier E.

THE PLANIMETER.



Now trace the line, moving in the direction travelled by the hands of a watch, stop at the starting point, and take the reading.

1st. Find the highest figure on the roller that has passed the zero on the vernier, moving to the left, which we will assume to be 4; now the construction of the instrument is such, that each figure on the roller represents an equal number of square inches.

2d, Find the number of *completed* divisions between 4 on the roller and zero on the vernier, which we will assume to be 5.

3d, Find the number of the mark on the vernier which coincides with some mark on the roller, which in this case may be 6.

We now have the exact reading, 4.56 or 4 56–100 inches area.

In measuring diagrams of more than 10 inches area, add 10 to the result.

To those who are perfectly familiar with the instrument, it is not necessary to place zeros so they coincide; but take the reading as it is, and subtract from the result. Should the second reading be less than the first, add 10 to the second reading before making the subtraction.

For instance, should the first reading be 8.42, and the second reading 2.68, add 10 to the second reading, thus: $2.68+10=12.68-8.42=4.26$ square inches.

If the area to be measured is very large, divide it by lines into areas of less than 20 square inches, and take separate measurements.

If the drawing is to a scale, multiply the result by the square of the ratio number of the scale.

Should we desire to find the area of a plan containing 5 square inches, drawn to a scale of 100 rods to the inch, we square the ratio number, and multiply by 5, thus: $100\times100=10{,}000\times5=50{,}000$ square rods.

In using the Planimeter for indicator diagrams, and for which it is *specially* adapted, we find the area of the diagram, according to the foregoing directions, which we will assume to be 2.48; we now measure the length of the diagram parallel with the atmospheric line, which we will say in this case is 4 inches. Now divide the area by the length; the quotient is the mean, or average height of the diagram in inches, which is .62 inches; this we multiply by the scale of the indicator, which we will assume to be 40; the product gives us 24.8 lbs. mean pressure on each square inch of the piston.

Expressed arithmetically $2.48\div4=.62\times40=24.8$.

It can also be used for measuring any regular or irregular plot or diagram.—[American Steam Gauge Company.

TABLE.

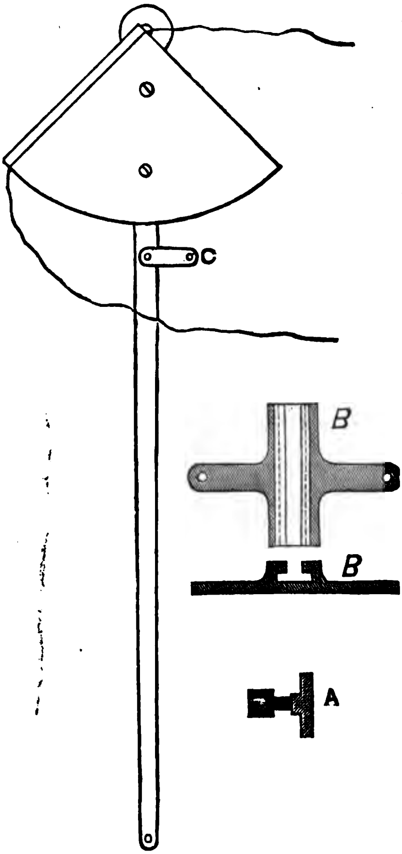
Showing the weight of the atmosphere, in lbs. avoirdupois, on 1 square inch, corresponding with different heights of the barometer, from 28 inches to 81 inches, varying by tenths of an inch.

Barometer in Inches.	Atmosphere in lbs.	Barometer in Inches.	Atmosphere in lbs.	Barometer in Inches.	Atmosphere in lbs.
28.0	13.72	29.1	14.26	30.1	14.75
28.1	13.77	29.2	14.31	30.2	14.80
28.2	13.82	29.3	14.36	30.3	14.85
28.3	13.87	29.4	14.41	30.4	14.90
28.4	13.92	29.5	14.46	30.5	14.95
28.5	13.97	29.6	14.51	30.6	15.00
28.6	14.02	29.7	14.56	30.7	15.05
28.7	14.07	29.8	14.61	30.8	15.10
28.8	14.12	29.0	14.66	30.9	15.15
28.9	14.17	30.0	14.70	81.0	15.19
29.0	14.21				

REDUCING MOTIONS.

Probably the simplest and best reducing motion for general use, is the Improved Brumbo Pulley as illustrated in the following cut. It is simply a narrow bar of wood, at least one and a half times as long as the stroke of the engine. The cord runs over an arc. (or preferably attached to pin link C), the centre of which is the pin on which the bar swings. The radius of the arc, or distance of pin C from the swinging point, to give the desired length of the diagram can be readily found by dividing the bar by the stroke and multiplying the quotient by the length of the diagram desired. The product will be the required radius. For example, if the bar is 30 inches long and the stroke 20 inches, and we wish to obtain a 3-inch diagram, we have 30 inches $\div$ 20 inches $= 1\frac{1}{2}$, $1\frac{1}{2} \times 3$ inches $= 4\frac{1}{2}$ inches, the radius required to give a diagram 3 inches in length. When the cross-head is in the middle of the stroke the swinging bar must be in the middle of its path. This apparatus has but few points, and is very simple. From suggestions made by Mr. Hill, of Hill, Clarke & Co., Boston. The author has made an improvement as shown in the cut. Instead of a link to connect bar with cross-head, as heretofore used, the lower end of bar is pivoted to a T-headed bolt, A, (or any other convenient devise), which slides in a grooved plate, B. This plate or devise must be attached to the cross-head in such a manner, and the swinging point of the bar should be in such a position that the bar will stand verticle when the piston is at half stroke. The bar also should be so located that when at half stroke, the lower centre will be as much below the line of motion as when at the ends of stroke it is above. It is not essential that the plate should be at the centre of cross-head pin, it may be placed above or below, or forward or back of it, as is most convenient. By this arrangement the motion of the cord upon a pin, C, in the bar, if the cord runs about parellel with the piston rod is coincident with that of the piston, and gives a correct line upon the diagram, which is not the case with the old plan.

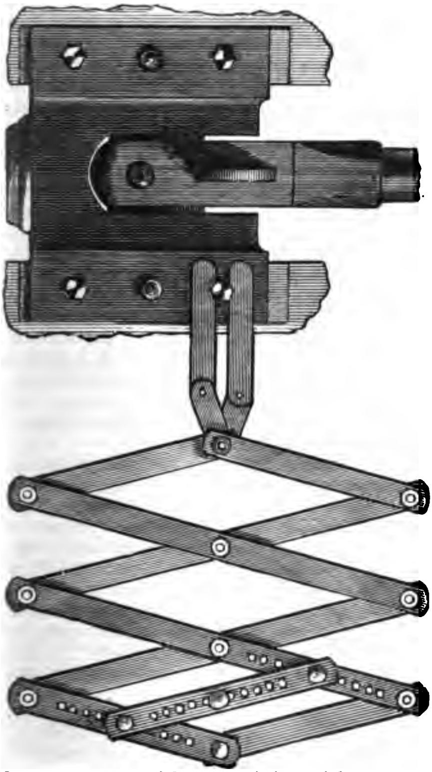
IMPROVED BRUMBO PULLEY.



THE PANTOGRAPH.

The Pantograph here illustrated is quite commonly used as a reducing motion. Although the Pantograph gives theoretically a perfect motion, owing to its complicated construction and many joints it soon becomes shaky, unless very nicely made, and gives erroneous results. Whatever reducing motion is used, its accuracy can be easily tested in the following manner: Lay off on the guides points at say $\frac{1}{4}$, $\frac{1}{2}$, $\frac{3}{4}$, etc., of the stroke. Connect the indicator with reducing motion in the same manner as for taking diagrams. When the cross-head is on either dead center, touch the pencil to the paper and make a vertical mark. In the same way make marks when the cross-head reaches each successive quarter point on the guides. If the marks are exactly at fourths on the card the motion on the cross-head has been accurately reduced. These directions given for reducing motions are general; some special cases require special modifications. Carrying pulleys and long cords should be avoided if possible. It is well to substitute piano wire for cord when any great length has to be used.

THE PANTOGRAPH.



The indicator having been placed in position and a correct reducing motion obtained, it is next necessary to adjust the length of the cord so that the drum will not strike the stops at either extreme of its rotation. Find about the length of cord required and make a loop at the end, so that when the hook on short piece of cord connected with the indicator is hooked in, the cord will be a little too long. Take up the extra length by tying knots in the cord until the drum rotates without striking either stop. This method may seem rather primitive, but it has been adopted by many of our best engineers after trying the various devices for shortening the cord.

After the cord is adjusted and a paper wrapped on the drum, open the indicator cock and allow the piston to play until the instrument has been thoroughly warmed by the steam, then press the pencil on the paper by the wood handle. After the pencil has remained on the paper during one revolution, draw it back, close the cock, then press the pencil on the paper and take the atmospheric line.

The pressure of the pencil on the paper can be adjusted by screwing

the handle in or out, so that when it strikes the stop there will be just enough pressure on the pencil to give a distinct fine line. The line should not be heavy, as the friction necessary to draw such a line is sufficient to cause errors in the diagram.

After the diagram has been taken, disconnect the cord to avoid any unnecessary wear on the drum.

On locomotives and engines, the speed of which is so great that it is difficult to hook in the loop, arrangements can easily be made so this will not have to be done. At the further end of the arc on the Brumbo pulley, insert an ordinary screw eye. Drive another screw eye firmly into a small hole drilled in the centre of the end of the bolt on which the bar swings. The cord from the indicator can then be carried through the eye at the end of the arc, and then through the eye in the end of the bolt and back to some convenient point near the instrument where it can be easily reached by the operator. Connect the cord with the instrument and draw it through the eyes until the drum will not strike the stops at its extreme positions. Then at the point on the cord just before the eye at the end of the arc, tie a small ring. When the cord is drawn taut by the operator, the ring stops the cord when it has been drawn through just enough to give the proper motion to the drum. As soon as the diagram and atmospheric line have been taken, slacken the cord and the drum will stop. This arrangement is very convenient on locomotives, as the cordcan be drawn taut with one hand while the diagram is taken with the other.

Make notes of as many of the following facts as possible: The day and hour of taking the diagram and the scale of the spring used. The engine from which the diagram was taken, which end and from which cylinder if one of a pair. The diameter of the cylinder, the length of the stroke, and the number of revolutions per minute. What per cent. of the piston displacement, the clearance and waste room is at each end of the cylinder. The boiler pressure from the gage, and, if the engine is condensing, the vacuum by the gage, and the temperature of the hot well. If the engine is compound, the pressure in the receiver.

It is often useful to make notes of special circumstances of importance, such as a description of the boiler, diameter and length of steam and exhaust pipes, temperature of the feed water, the quantity of water and fuel consumed per hour, etc. On a locomotive find the exact circumference of the drivers, by measuring on the track the exact distance passed over during a comple.e revolution. Note also the position of the throttle and the link, the size of the blast orifice, the weight of the train, and the gradient.

On diagrams from marine engines, note, in addition to the general facts, the speed of the ship in knots per hour, the direction and force of the wind, the direction and state of the sea, the diameter and pitch of the screw, the kind of coal, the amount consumed and the ashes made per watch.—[Crosby Steam Gage and Valve Co.

INDICATOR DIAGRAMS.

The degree of excellence to which the steam engines of the present time have attained, is due more to the use of the indicator than to any other one thing, as a careful study of indicator diagrams taken under different conditions of load, pressure, etc., is the only means of becoming familiar with the action of steam in an engine, and of gaining a definite knowledge of the various changes of pressure that take place in the cylinder.

An indicator diagram is the result of two movements, namely: a horizontal movement of the paper and a vertical movement of the pencil, and

consequently represents by its length the stroke of the engine on a reduced scale, and by its height at any point, the pressure on the piston at a corresponding point in the stroke.

The pressure shown is measured by a scale graduated to correspond with the spring used.

The most common scales are those numbered 40, 50 and 60; that is, an inch vertical height on the diagram represents, according to the spring used, 40, 50 or 60 pounds of steam per square inch in the cylinder.

A single diagram shows the pressure acting on one side of the piston during both the forward and return stroke, with all the changes of pressure properly located in the stroke. To show the corresponding pressure on the other side another diagram must be taken from the other end of the cylinder. When the three-way cock is used, the diagrams from both ends are usually taken on the same paper, as in Fig. 2.

Fig. 1.

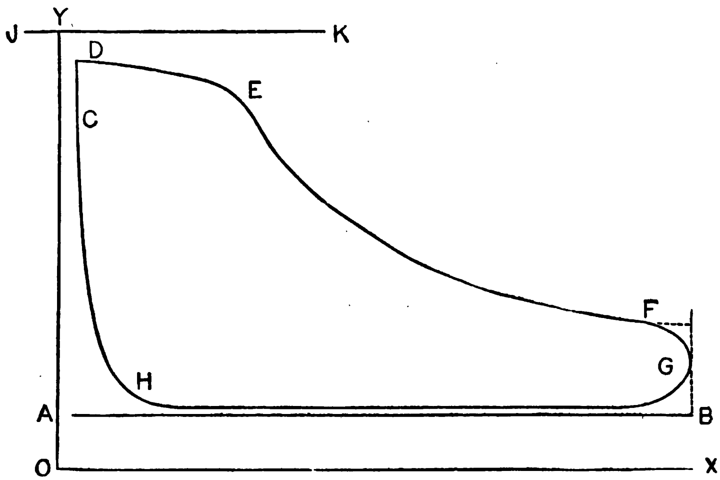


Diagram from an improved Greene engine. Cylinder, 16 inches in diameter, 36 inches stroke. Boiler pressure, 100 lbs. 80 revolutions per minute. Scale 50.

DEFINITIONS.

The names which have been given to the various points and lines on the diagram are as follows (see Fig. 1) :—

The Atmospheric Line, A B, is a line drawn by the pencil of the indicator when the connections with the engine are closed and both sides of the piston are open to the atmosphere. This line represents on the card the pressure of the atmosphere, or zero gage pressure.

The Vacuum Line, O X, is a reference line usually drawn about 14 7-10 pounds by scale below the atmospheric line. It represents a perfect vacuum, or absence of all pressure.

The Clearance Line, O Y, is another reference line drawn at a distance from the end of the diagram equal to the same per cent. of its length as the clearance and waste room is of the piston displacement. The distance be-

tween the clearance line and the end of the diagram represents the volume of the clearance and waste room of the ports and passages at the end of the cylinder.

The Line of Boiler Pressure, J K, is drawn parallel to the atmospheric line, and at a distance from it by scale equal to the boiler pressure shown by the gage. The difference in pounds between it and D E shows the loss of pressure due to the steam pipe and the ports and passages in the engine.

The Admission Line, C D, shows the rise of pressure due to the admission of steam to the cylinder by opening the steam valve. If the steam is admitted quickly when the engine is about on the dead centre, this line will be nearly vertical.

The Steam Line, D E, is drawn when the steam valve is open and steam is being admitted to the cylinder.

The Point of Cut-Off, E, is the point where the admission of steam is stopped by the closing of the valve. It is difficult to determine the exact point at which the cut-off takes place. It is usually located where the outline of the diagram changes its curvature from convex to concave.

The Expansion Curve, E F, shows the fall in pressure as the steam in the cylinder expands doing work.

The Point of Release, G, shows when the exhaust valve is open.

The Exhaust Line, F G, represents the change in pressure that takes place when the exhaust valve opens.

The Back Pressure Line, G H, shows the pressure against which the piston acts during its return stroke. On diagrams taken from non-condensing engines it is either coincident with or above the atmospheric line, as in Fig. 1. On cards taken from a condensing engine, however, it is found below the atmospheric line, as in Fig. 2, and at a distance greater or less according to the vacuum obtained in the cylinder.

The Point of Exhaust Closure, H, is the point where the exhaust valve closes. It cannot be located very definitely, as the change in pressure is at first due to the gradual closing of the valve.

The Compression Curve, H C, shows the rise in pressure due to the compression of the steam remaining in the cylinder after the exhaust valve has closed.

The Mean Effective Pressure (M. E. P.) is the mean net pressure urging the piston forward.

The Initial Pressure is the pressure acting on the piston at the beginning of the stroke.

The Terminal Pressure is the pressure above the line of perfect vacuum that would exist at the end of the stroke if the steam had not been released earlier. It is found by continuing the expansion curve to the end of the diagram, as in Fig. 5. This pressure is always measured from the line of perfect vacuum, hence it is the *absolute* terminal pressure.—[Crosby Steam Gage and Valve Co.

HORSE POWER.

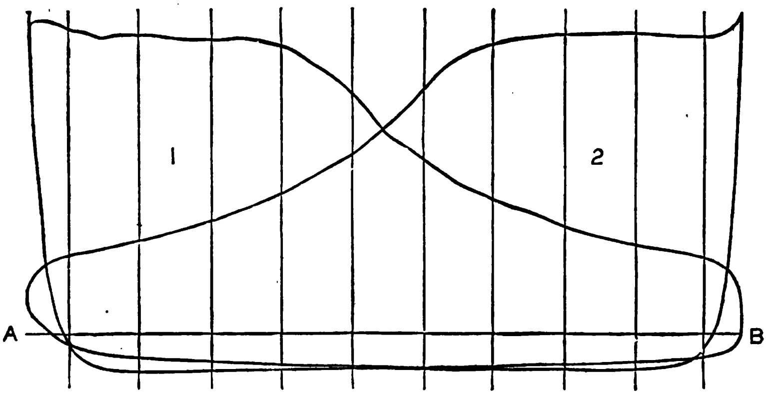
Watt ascertained by experiment that the power of London draught horses, exerted with ordinary continuance, was to lift 33,000 lbs. one foot in one minute. This is now the standard to determine the horse power of an engine. The standard horse power, as above stated, is 33,000 ft. lbs. A foot lb. is 1 lb. lifted 1 ft. high per minute, or equivalent amount of force, or 12 lbs. lifted 1 inch per minute. To calculate the horse power, multiply the area of the piston in square inches, by twice the length of the stroke in feet, and the product by the number of revolutions per minute. This product is known as the "Piston Displacement." Divide this product by

33,000 and the result is the "Horse Power Constant," or the power developed for every pound of Mean Effective Pressure (abbreviated M. E. P.) Multiply the quotient by the M. E. P., ascertained from the diagram as hereafter explained, and the result is the indicated horse power. It is convenient for the engineer to know the Horse Power Constant of his engine. Suppose it is 20 x 30 inches, making 120 revolutions per minute, thus:

Area of piston,	314.16	sq. inches,
Multiplied by twice the stroke,	5	feet,
	1,570.80	
Multiplied by rev. per minute,	120	
Divided by standard of H. P.	33,000)188496.00(5.712	H. P. Constant.
	165000	40 lbs. M. E. P.
	234960	228.480 I. H. P.
	231000	
	39600	
	33000	
	66000	
	66000	

There are several approximate methods for computing the mean effective pressure. One of the most convenient is as follows: Draw on the diagram ten, or any convenient number of lines, as in Fig. 2, perpendicular

Fig. 2.



Diagrams from Hartford engine. Cylinder, 16 x 24 inches. Boiler pressure, 87 lbs. Vacuum per gage, 23½ inches. 130 revolutions per minute. Scale, 50.

to the atmospheric line and equal distances apart. The first and last of these ordinates are drawn half of the distance from the ends of the diagram that each ordinate is from another, as the height of each is supposed to represent the average height of the space in the middle of which it

stands. Measure the length of each ordinate within the lines of the diagram, and divide the sum of their lengths by the number of ordinates used. Multiply the average length thus found by the scale of the spring used, and the result will be the mean effective pressure of the diagram. It is sometimes convenient to find the sum of the lengths of the ordinates by using a sliding rule, or by marking off the different lengths successively on a strip of paper.

Fig. 3.

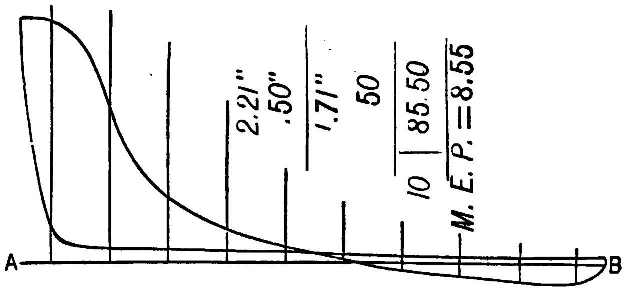


Diagram from Buckeye engine. Cylinder, 16 x 32 inches. 100 revolutions per minute. 50 scale.

In case there is a loop in the diagram, as in Fig. 3, caused by the steam expanding below the back pressure line, when the engine is non-condensing, the ordinates below the back pressure line are negative, and the sum of their lengths must be subtracted from the sum of the lengths of the ordinates above back pressure.

To Calculate the Horse Power of an Engine.—Multiply the mean net area of the piston in square inches, by the mean effective pressure (M. E. P.) in pounds per square inch acting on the piston throughout the strokes in both directions, ascertained from indicator diagrams taken from both ends of the cylinder. Multiply this product by the distance through which the piston travels in feet per minute and divide by 33,000.

$$\text{Thus, I.H.P} = \frac{\text{Mean net area of piston} \times \text{M.E. P.} \times \text{revs. per min.} \times 2 \times \text{stroke}}{33{,}000.}$$

When there are a number of diagrams taken from the same engine to be worked up, the calculations may be simplified by multiplying the area of the piston by twice the length of the stroke, and dividing the result by 33,000. This gives the "constant of the engine," that is, the power that would be developed at one revolution per minute with one pound mean effective pressure. Multiply this constant by the number of revolutions per minute, and then by the mean effective pressure, and the product will be the I. H. P. If the number of revolutions is the same for several diagrams as is frequently the case with stationary engines, the calculation may be still further simplified by multiplying the "*constant of the engine*" by the number of revolutions per minute. This will give the "*Horse Power Constant*," or the horse power developed per pound M. E. P. Multiply the Horse Power Constant by the M. E. P., and the product will be the Indicated Horse Power (I. H. P.)

THEORETICAL CURVE.

It is sometimes interesting to compare the expansion curve of the diagram with the theoretical curve that would be drawn if the steam was a perfect gas expanding under perfect conditions. The rectangular hyperbola, which is easily drawn, serves very well as an approximation to the ideal curve. If it is required to have the theoretical curve coincide with

Fig. 4.

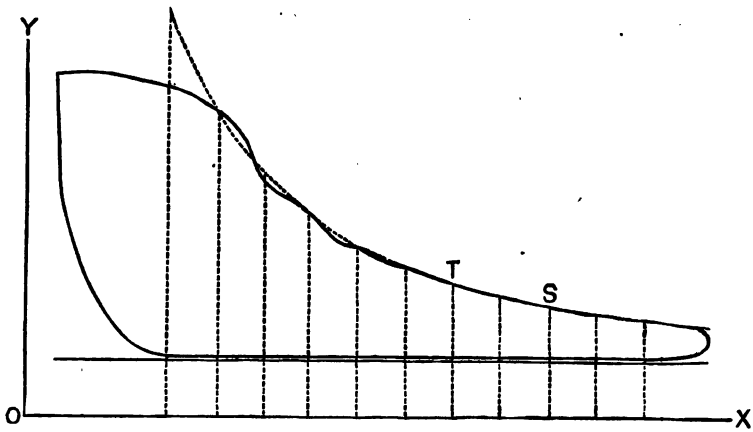


Diagram from Porter-Allen engine. Cylinder 11¼ x 20 inches. 230 revolutions per minute. Scale 50. Clearance, 4½ per cent.

the expansion curve at any point, as at S, the properties of the hyperbola are such, if the distance of S from O Y, the clearance line, be multiplied by the height of S above O X, the vacuum line, the height of any other point on the theoretical curve can be found by dividing this product by the distance of the point from O Y.

For example (see Fig. 4): S is 2.75 inches from O Y and .58 of an inch from O X. $2.75 \times .58 = 1.595$.

To find the height of a point, T, above O X, which is 2.25 inches distant from O Y, divide the constant, 1.595 by 2.25, and we have .71, which is the required height in inches of the point above O X.

In the same way other points can be located, and a curve drawn through them will be the required theoretical curve, as shown in Fig. 4. The theoretical curve will often come much higher at one end or the other, above the expansion curve, than it does on the diagram in the figure. The initial point of the theoretical curve may be taken at any point on the expansion curve, but it is usually best to take it just before the point of release.

STEAM CONSUMPTION.

When comparing the economy of the steam engines, and estimating the loss due to the mal-adjustment of the valves, it is often instructive to know

the amount of steam consumed per horse power per hour that is accounted for by the indicator diagram. The steam not being a perfect gas or vapor, but usually having more or less water mechanically mixed with it, and also being subject to loss of heat by radiation, and loss from condensation and re-evaporation in the cylinder, the rate of steam consumption shown by the indicator diagram is almost always considerably below the actual rate found by weighing the water fed to the boiler.

We give a convenient rule and computation table compiled by Edwin F. Williams, M. E., for determining the amount of steam consumed per horse power per hour accounted for by the indicator diagram. To use the rule it is only necessary to know the mean effective pressure, and the absolute terminal pressure of the diagram to be computed.

Rule. Find the weight per cubic foot of steam in column 4 corresponding to the absolute terminal pressure of the diagram in column 3. Divide this weight by the ***rate number*** found in column 2 opposite the mean effective pressure in column 1. Multiply the quotient by the constant number 32.32, and the product will be the weight of dry steam per indicated horse power per hour, subject to correction for clearance and compression, which may be done by Mr. J. W. Thompson's method as follows: Fix the terminal pressure at point O, Fig. 5, where it would have been if the steam

Fig. 5.

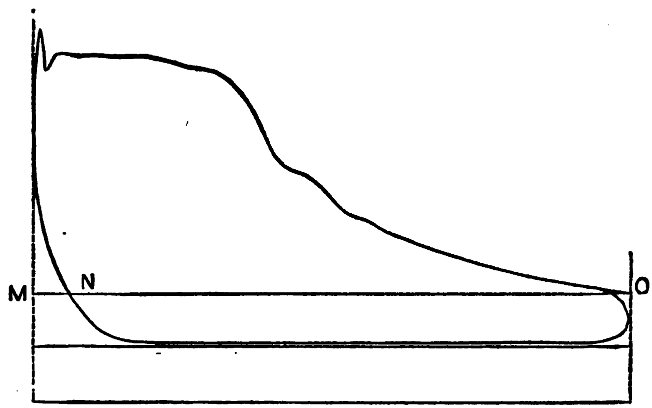


Diagram from Porter-Allen engine. Cylinder, 22 x 36 inches. 140 revolutions per minute. Scale, 50.

had not been released until the end of the stroke was reached. Second, draw the line O M parallel with the atmospheric line. It cuts the compression curve at N, at which point the quantity of steam exhausted from the clearance has been restored, and the consumption will be as much less than the rule shows as the line O N is shorter than the line O M. Third, multiply the result obtained by the rule, by the length of the line O N, and divide by the length of O M. The result will be the rate of steam consumption, corrected for clearance and compression.

Following is the Computation Table:—

STANDARD RATES.		COL. 3. Terminal Pressures Absolute.	COL. 4. Weight per Cubic foot.
COL. 1. M. E. P.	COL. 2. Rate.		
5	.0117		
6	.0141		
7	.0164	5	.0138
8	.0188	6	.0163
9	.0211	7	.0189
10	.0235	8	.0214
11	.0258	9	.0239
12	.0285	10	.0264
13	.0305	11	.0289
14	.0329	12	.0314
15	.0352	13	.0338
16	.0376	14	.0362
17	.0399	15	.0387
18	.0423	16	.0411
19	.0446	17	.0435
20	.0470	18	.0459
21	.0493	19	.0483
22	.0517	20	.0507
23	.0540	21	.0531
24	.0564	22	.0555
25	.0586	23	.0580
26	.0611	24	.0601
27	.0634	25	.0625
28	.0658	26	.0650
29	.0681	27	.0673
30	.0705	28	.0696
31	.0728	29	.0719
32	.0752	30	.0734
33	.0775	31	.0766
34	.0799	32	.0789
35	.0822	33	.0812
36	.0846	34	.0835
37	0869	35	.0858
38	.0893	36	.0881
39	.0916	37	.0905
40	.0940	38	.0929
41	.0963	39	.0952
42	.0987	40	.0974
43	.1010	41	.0996
44	.1034	42	.1020
45	.1057	43	.1042
46	.1081	44	.1065
47	.1104	45	.1089
48	.1128	46	.1111
49	.1151	47	.1133
50	.1175	48	.1156
51	.1198	49	.1179
52	.1222	50	.1202
53	.1245	51	.1224
54	.1269	52	.1246
55	.1292	53	.1269
56	.1316	54	.1291

EXAMPLE OF WILLIAMS' RULE.

EXAMPLE.—In Fig. 5. the absolute terminal pressure of the diagram is 28, and the mean effective pressure is 42 pounds. The weight per cubic foot at the terminal (col. 4) is .0696. The rate number in col. 2 opposite the M. E. P. is .0987. Then by the rule,

$$.0696 \div .0987 \times 32.32 = 22.79.$$

which is the number of pounds of steam per indicated horse power per hour, not taking clearance and compression into account.

The line O M is 3.14 inches in length, and the line O N is 2.95 inches; then to correct for clearance and compression,

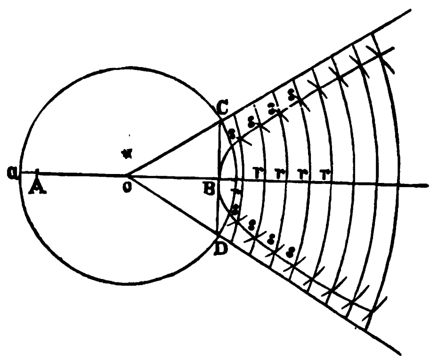
$$22.79 \div 3.14 \times 2.95 = 21.41 \text{ pounds},$$

which is the amount of steam per horse power per hour, accounted for by the indicator, corrected for both clearance and compression.—[Crosby S. G. and V. Co.

TO DESCRIBE AN HYPERBOLA.

A method of describing this curve, with cut, is here given, for the purpose of enabling those not familiar with drawing the curve, to get a better idea of its properties.

It has no special reference to the indicator diagrams shown, but will be of some assistance to those desiring to make the theoretical expansion curve. One half of the curve shown would be the form of the expansion line. From the point of cut-off, to the end of stroke in a diagonal line, would be the transverse diameter. The diameter of the cylinder would be the conjugate.

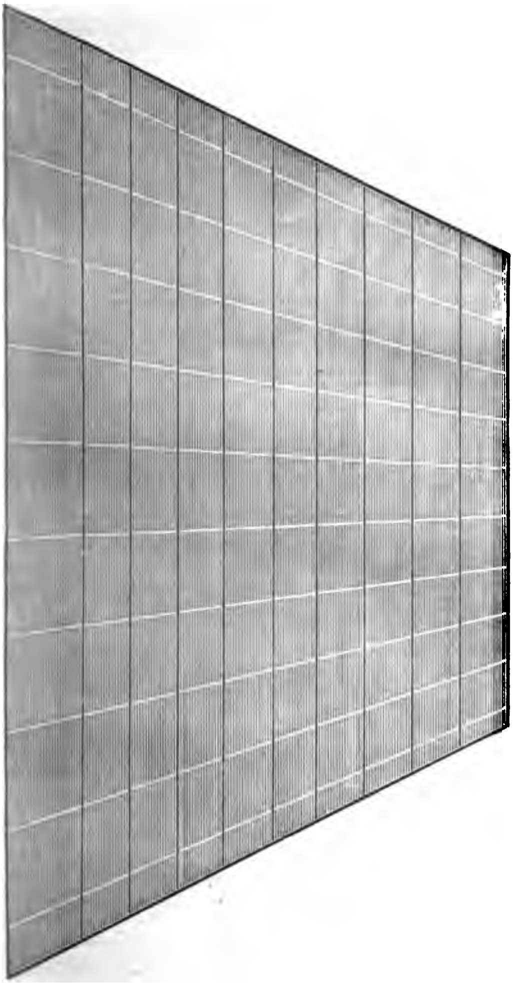


Let A B equal the longest or transverse diameter, and C D, perpendicular to it, the conjugate, and let the line A B be produced or extended from its respective limits each way, as to *a*, *r*, *r*, etc. Bisect A B in *o*, and with the radius *o* C, or *o* D, and *o* as the centre, describe the circle C *e* D *a*. Divide A B produced from B, into any number of parts, as *r*, *r*, *r*, etc., and with the radii A *r* and B *r*, and the foci *a* and *e* as centres, describe arcs cutting each other as in *s s*, etc. The intersections of the arcs with each other will define the curve of the hyperbola.

CALCULATING DIAGRAMS.

The use of the planimeter is the best method of obtaining the correct area of a diagram, but when this is not at hand the following constructed scale is simple, very correct, and easily learned.

Fig. 0.



For a small diagram not over 5 inches long, the scale (Fig. 0), full size, will answer the purpose.

The diagonal white lines are divided into equal divisions or spaces as seen. The parallel black lines are to facilitate the placing of the diagram upon the scale.

Take the diagram from the indicator, draw two perpendicular lines the length of the card, and cut off the bottom parallel with the atmospheric line. Place the bottom edge parallel on the scale at the right position to get the length of the diagram. Mark the divisions to correspond with the white lines, the two end spaces being only half as wide as the others. Measure with the scale corresponding with the spring, the distance from atmospheric line (if a non-condensing engine, if condensing from indicated vacuum line) to the steam line at each point of division, add the whole together, point off one decimal to the right, which divides it by ten, the number of divisions, and gives the M. E. P. in lbs. and tenths for that end. Take the other end in the same way, add them together and divide by two, which gives M. E. P. This result multiplied by "Constant" at 1 lb., pressure, gives the horse power. If the steam line falls below the atmospheric line that portion is negative and must be deducted as shown in Fig. 3, page 18.

Indicated Horse-Power for each Pound Average Pressure on a Square Inch, with Different Diameters and Speeds of Pistons.

Diameter of Cylinder.	Speed of Piston in Feet a Minute.									
	240	300	350	400	450	500	550	600	650	750
inches.										
4	.091	.114	.133	.152	.171	.19	.209	.228	.247	.285
4½	.115	.144	.168	.192	.216	.24	.264	.288	.312	.36
5	.144	.18	.21	.24	.27	.30	.33	.36	.39	.45
5½	.173	.216	.252	.288	.324	.36	.396	.432	.468	.54
6	.205	.256	.299	.342	.385	.428	.471	.513	.555	.641
6½	.245	.307	.391	.409	.461	.512	.563	.614	.698	.800
7	.279	.348	.408	.466	.524	.583	.641	.699	.756	.874
7½	.321	.401	.468	.534	.602	.669	.735	.802	.869	1.002
8	.365	.456	.532	.608	.685	.761	.837	.912	.989	1.121
8½	.413	.516	.602	.688	.774	.86	.946	1.032	1.118	1.29
9	.462	.577	.674	.770	.866	.963	1.059	1.154	1.251	1.444
9½	.515	.644	.751	.859	.966	1.074	1.181	1.288	1.395	1.610
10	.571	.714	.833	.952	1.071	1.190	1.309	1.428	1.547	1.785
10½	.63	.787	.919	1.050	1.181	1.313	1.444	1.575	1.706	1.969
11	.691	.864	1.008	1.152	1.296	1.44	1.584	1.728	1.872	2.160
11½	.754	.943	1.1	1.257	1.414	1.572	1.729	1.886	2.043	2.357
12	.820	1.025	1.195	1.366	1.540	1.708	1.880	2.050	2.222	2.564
13	.964	1.206	1.407	1.608	1.809	2.01	1.211	2.412	2.613	3.015
14	1.119	1.398	1.631	1.864	2.097	2.331	2.564	2.797	3.029	3.495
15	1.285	1.606	1.873	2.131	2.409	2.677	2.945	3.212	3.479	4.004
16	1.461	1.827	2.131	2.436	2.741	3.045	3.349	3.654	3.958	4.567
17	1.643	2.054	2.396	2.739	3.081	3.424	3.766	4.108	4.450	5.135
18	1.849	2.312	2.697	3.083	3.468	3.854	4.239	4.624	5009	5.78
19	2.061	2.577	3.006	3.436	3.865	4.295	4.724	5.154	5.583	6.442
20	2.292	2.855	3.331	3.807	4.285	4.759	5.234	5.712	6.186	7.188
21	2.518	3.148	3.672	4.197	4.722	5.247	5.771	6.296	6.820	7.869
22	2.764	3.455	4.031	4.607	5.183	5.759	6.334	6.911	7.486	8.638
23	3.021	3.776	4.405	5.035	5.664	6.294	6.923	7.552	8.181	9.44
24	3.289	4.111	4.797	5.482	6.167	6.853	7.538	8.223	8.908	10.279

25	3.569	4.461	5.105	5.948	6.692	7.436	8.179	8.923	9.566	11.058
26	3.861	4.826	5.630	6.435	7.239	8.044	8.848	9.652	10.456	12.065
27	4.159	5.199	6.066	6.932	7.799	8.666	9.532	10.399	11.265	12.998
28	4.477	5.596	6.529	7.462	8.395	9.328	10.261	11.193	12.125	18.991
29	4.805	6.006	7.007	8.008	9.009	10.01	11.011	12.012	13.013	15.015
30	5.141	6.426	7.497	8.568	9.639	10.71	11.781	12.852	13.928	16.065
31	5.486	6.865	8.001	9.144	10.287	11.43	12.573	13.716	14.866	17.145
32	5.846	7.308	8.526	9.744	10.962	12.18	13.398	14.616	15.834	18.270
33	6.216	7.770	9.065	10.360	11 655	12.959	14.245	15.54	16.835	19.425
34	6.59	8.238	9.611	10.984	12.357	13.73	15.103	16.476	17.849	20.595
35	6.993	8.742	10.199	11.656	13.113	14.57	16.027	17 484	18.941	21.855
36	7.401	9.252	10.794	12.336	13.878	15.42	16.962	18 504	20.046	23.130
37	7.819	9.774	11.403	13.032	14.861	16.29	17.919	19.548	21.177	24.435
38	8.246	10.308	12.026	13.744	15.462	17.18	18.898	20.616	22.334	25.770
39	8.648	10.86	12.67	14.48	16.29	18.1	19.91	21.62	23.58	27.15
40	9.139	11.424	13.328	15.232	17.136	19.04	20.944	22.848	24.752	28.560
41	9.604	12.006	14.007	16.008	18.009	20.00	22.011	24.012	26.013	30 015
42	10.065	12.594	14.693	16.792	18.901	20.99	23.089	25.188	27.287	31.485
43	10.56	13.20	15.4	17.6	19.8	22.0	24.2	26.4	28.6	33.0
44	11.046	13.818	16.121	18.424	20.727	23.03	25.333	27.636	29.939	34.545
45	11.563	14.454	16.863	19.272	21.681	24.09	26.399	28.908	31.317	36.135
46	12.086	15.128	17.626	20.144	22.662	25.18	27.698	30.216	32.754	37.770
47	12.614	15.768	18.396	21.024	23.652	26.28	28.908	31.536	34.164	39.420
48	12.846	16.446	19.187	21.928	24.669	27.41	30.151	32.152	35.633	41.115
49	12.913	17.142	19.999	22.856	25.713	28.57	31.427	34.284	37.141	42.855
50	14.28	17.85	20.825	23.8	26.775	29.75	32.725	35.7	38.675	44.625
51	14.832	18.54	21.665	24.76	27.855	30.95	34.045	37.08	40.205	46.425
52	15.437	19.296	22.512	25.728	28.944	32.16	35.376	38.592	41.808	48.240
53	16.041	20.052	23.394	26.736	30.078	33.42	36.762	40.104	43.446	50.13
54	16.656	20.82	24.29	27.76	31.23	34.7	38.17	41.64	45.11	52.05
55	17.275	21.594	25.193	28.792	32.391	35.99	39.589	43.188	46.787	53.985
56	17.909	22.386	26.117	29.848	33.579	37.31	41.041	44.772	48.503	55.965
57	18.557	23.196	27.062	30.928	34.794	38.66	42.526	46.392	50.258	57.99
58	19.214	24.018	28.021	32.024	36.027	40.03	44.033	48.036	52.039	60.045
59	19.902	24.852	28.994	33.136	37.278	41.42	45.562	49.704	53.846	62.13
60	20.558	25.698	29.981	34.264	38.547	42.83	47.113	51.396	55 679	64.245

TABLE OF HORSE POWER CONSTANT.

For convenience of making calculations, a Table of Horse Power Constant for varied sizes of cylinder and different speeds of piston per minute is given on pages 24 and 25, (arranged by W. A. Hammett, M. E.,) for calculating the diagrams given with planimeter from page 10, or scale on page 23.

Having learned how to apply the Indicator and having understood its reading by means of the preceding illustrations, it is only necessary after taking a diagram to see by careful study where improvement can be made. If your engine is high speed, you will require more lead to your steam valves, and more compression to your exhaust, than for a low speed. If the piston speed is 600 ft. per minute or more, the compression line where it intersects the admission line, should be about one-half the height of the card if non-condensing, if condensing somewhat less. If the piston speed is not more than 450 ft. per minute, one-sixth the height of the card would be sufficient, particularly if the point of cut-off is not more than one-fourth of the stroke.

SETTING OF VALVES.

In setting the valves for the first time of a newly set-up engine, after equalizing the length of the eccentric rod so that the valves will open equal, to have the engine run *forward*, or over, that is, standing at the back end of the cylinder, facing the fly-wheel, the top of which runs from you (if forward) set the throw of the *eccentric forward of the crank*, so that the valve will open the steam port about 1-32 of an inch if a long stroke, and piston speed about 400 ft. per minute, increase the lead as the speed of piston of engine is increased until you may have on a high speed locomotive as much as ⅜in. lead. To run an engine backwards, or under, you have only to set the throw of the eccentric back of the crank instead of forward, as in the other case.

THE KIND OF INDICATOR.

Engineers, like other people, have their preferences, and generally would speak well of the instrument they have been accustomed to use. The author of this work has used the "Crosby" more than any other, but has also used the "Thompson," and the "Tabor." and has found all these instruments well adapted to *high speed* and *pressure*, they also work equally well for low speed and pressure. Care should always be taken in using any instrument, to adapt the spring to the pressure, as explained on page 28; also use a drum the right diameter to produce a proper proportioned card. A slow moving engine with long stroke. requires a larger drum than a quick moving engine with a short stroke. The object being to get a card of good proportions as to length and height, to facilitate measurement with accuracy. Many run to both extremes in the size of cards.

Some indicators are made with a large and small drum interchangable, this is very convenient where the engineer is required to indicate several kinds of engines.

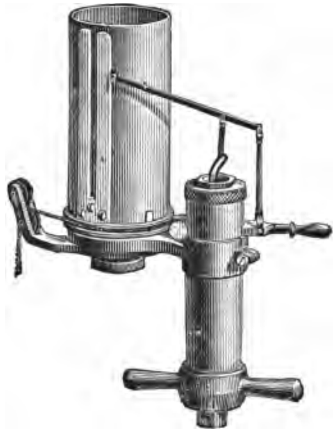
With one pair of instruments and two drums to each, he has what is equivalent to four instruments. We think it better to use an indicator at

each end of the cylinder, rather than one in the centre, thus avoiding a three-way cock and long pipe connections, which causes condensation.

Views of the "Thompson" indicator have been given on page 8. A cut of the "Crosby" and also of the "Tabor" is here introduced. The purchaser can thus have a choice of *three first-class instruments.*

CROSBY INDICATOR.

TABOR INDICATOR.



There are some additional advantages not previously mentioned, which seems more fully to develop the subject, as shown in the following extract.

"The steam engine indicator is an instrument for drawing a diagram on paper which shall accurately represent the various changes of pressure on the piston of the steam engine during both the forward and return stroke. The indicator was invented by James Watt, and was extensively used by him in perfecting his engines. Of the earlier forms of the instrument it may simply be said that they were unfit for use on engines running at any but the very slowest speeds. Even then, owing to their many imperfections, their indications were often misleading, and of little use, beyond showing the points in the stroke at which the valves opened and closed; a service of great value, but affording only a small part of the information to be gained from a really good instrument. The Richards Indicator, designed by Mr. Charles B. Richards, contained many improvements on the instruments previously used. It was well adapted to engines running at the speeds commonly employed at the time it was invented, and was for years the standard indicator in both Europe and America. The weights of the moving parts of this instrument are, however, so great that their inertia and momentum seriously affect the accuracy of the diagrams, and render it unfit for use under the conditions of high pressures and high speeds met with in ordinary practice at the present time. Some of the leading items of information to be obtained by the use of the indicator are:—

The arrangement of the valves for admission, cut-off, release and compression of steam.

The adequacy of the ports and passages for admission and exhaust, and when applied to the steam chest, the adequacy of the steam pipes.

The suitableness of the valve motion in point of rapidity at the right time.

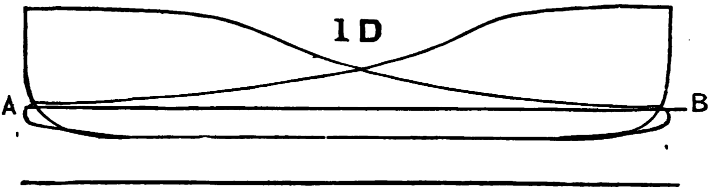
The quantity of power developed in the cylinder, and the quantity lost in various ways—by wire drawing, by back pressure, by permature release, by mal-adjustment of valves, leakage, etc.

It is useful to the designers of steam engines in showing the redistribution of horizontal pressures at the crank pin, through the momentum and inertia of the reciprocating parts, and the angular distribution of the tangential component of the horizontal pressure; in other words, the rotative effect around the path of the crank.

Taken in combination with measurements of the exhaust steam, with the amount of fuel used, the indicator furnishes many other items of importance when the economical generation and use of steam are considered.—[Crosby S. G. and V. Co.

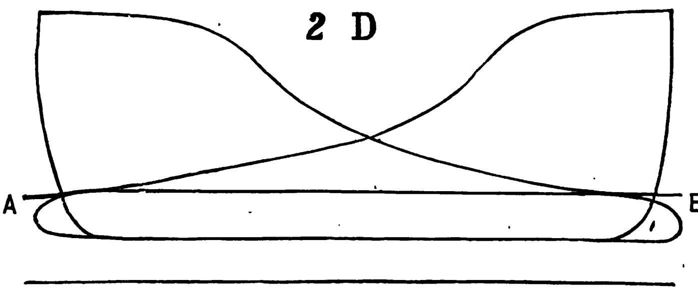
INDICATOR SPRINGS.

The spring of the Indicator should be the proper proportion to the pressure of the steam used, so that the diagram would not be more than $1\frac{3}{4}$ inches high at the admission line. To illustrate: figures 1, 2, 3 D, represent cards taken from a Hartford engine, each showing about the same amount of work, but quite different in appearance.



Steam, 30 lbs. Vacuum, 20 in. M. E. P., 20 lbs. I. H. P., 112.20

Figure 1 D, a 50 spring or scale, as usually called.

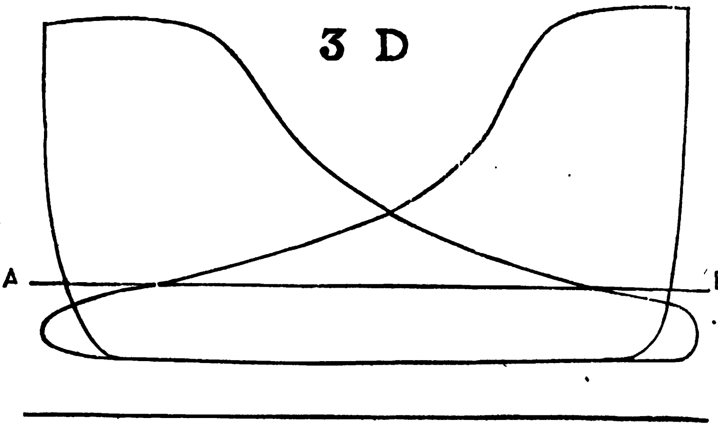


Steam, 36 lbs. Vacuum, 20 in. M. E. P., 19.9 lbs. I. H. P., 111.63.

Figure 2 D, a 30 scale.

The first shows the steam as following too far before cutting off (although the initial pressure is but 30, and the load is a trifle greater than the other cards. This accounts in a great measure for the relative difference). Figure 3 D, with a 20 spring, shows the card as much too high as Fig. 1 is too low. The point wished to make clear, is that the steam pressure should exceed the spring sufficient to show the card about $1\frac{1}{2}$ inches high.

Figure 2 with a spring of 30, is about that proportion of diagram, and more liable to be correct.

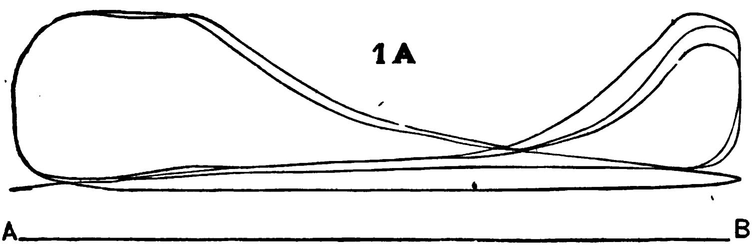


Steam, 35 lbs. Vacuum, 21 in. M. E. P., 19.7 lbs. I. H. P., 110.51.

Figure 3 D, a 20 scale.

NOTE. [To simplify the following diagrams, the back pressure is included with the M. E. P., but the amount of B. P. is stated.]

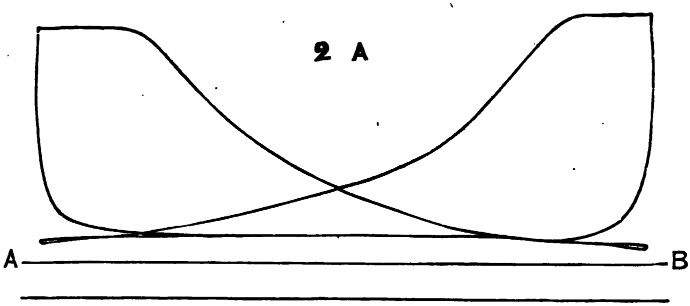
In diagrams 1 and 2 A, we have cards taken from a pair of Wheelock engines 24x48 inches, making 57 revolutions per minute. They had been running 12 years and had never before had an indicator applied. The engineer considered that the valves were right and the engines doing their duty well, which was generally about 300 horse power. Card 1 A, was



Head end steam,	73 lbs.	Crank end steam,	73 lbs.
Back pressure,	13.3 "	Back pressure,	17.5 "
M. E. P.,	37. "	M. E. P.,	25.2 "
I. H. P.,	234.21	I. H. P.,	157.50
Less back pressure I. H. P.,	149.38	Less back pressure,	48.12

the first taken from the left-hand cylinder. The average of the head end shows that it is doing about double the work that the average of the crank end is doing, for there are three distinct lines on the latter, and the gov-

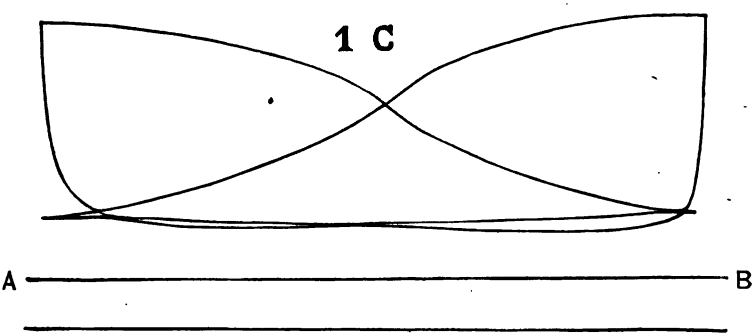
ernor is making spasmodic efforts to keep one end at uniform speed with the other. Had not this engine been one of a pair connected together and working similarly (the serious imperfections being in the same ends in each cylinder, and also connected with two water wheels, which assisted very much in controlling the speed), it is easy to see that the effect would have been disastrous. Card 2 A, shows the same cylinder after the valves



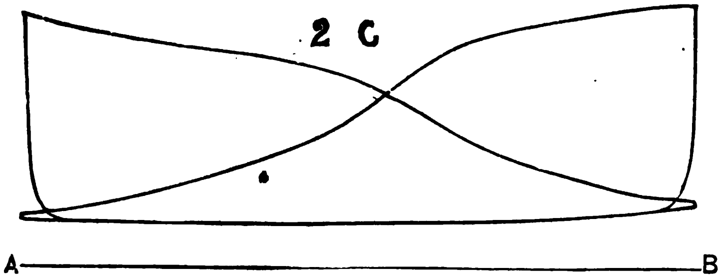
Both ends steam, 73 lbs. Back pressure, 7.17 lbs. M. E. P., 27.7 lbs. I. H. P., 173.12. Less back pressure, 128.12.

had been properly set by the indicator. The most of the adjustment was made while the engine was running and doing its work, the valves of course not having been seen. The gross horse power, including back pressure of card 1 A, is 391.71, while that of 2 A is but 173.12, showing 218 59 H. P. in favor of 2 A, on gross power, and a difference of 69.38 on net power. About the same power was required for the regular work in each case.

These cards were taken August 30th and September 1st, 1883, just previous to the great drought and low water of that year. Had not the indicator been applied and changes made as designated, the engine could not have possibly done the work through the drought. More work was afterwards added, and this same pair of engines without any farther change, indicated 536.87 horse power as shown in cards 1 and 2 C.

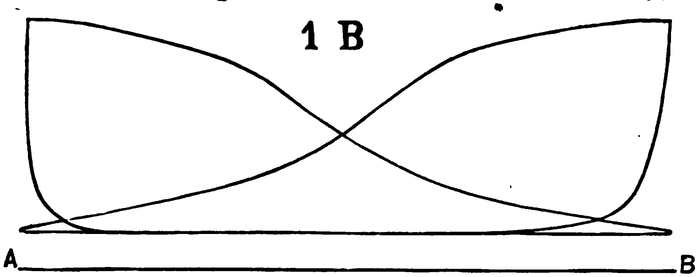


Steam, 77 lbs. Back pressure, 13 lbs. M. E. P., 43 lbs. I. H. P., 268.75. Less back pressure, 187.50.

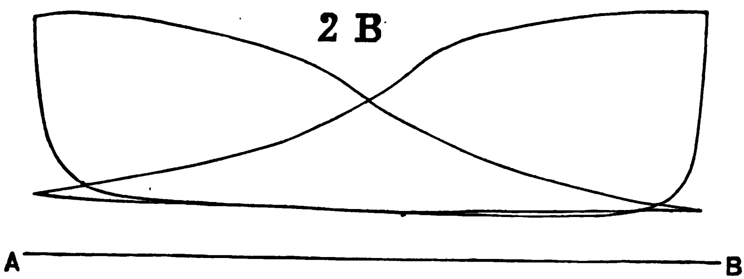


Steam, 78 lbs. Back pressure, 11.8 lbs. M. E. P., 42.9 lbs. I. H. P., 268.12. Less back pressure 194.37.

There are two important points shown in cards 1 and 2 C, and 1 and 2 B, all from the same engine: these are the great back pressure, and the falling off of pressure on the steam line previous to cut-off due to *small pipes and ports*, not being more than one-half the area necessary, when



Steam, 78 lbs. Back pressure, 10 lbs. M. E. P., 38.2 lbs. I. H. P., 238.75. Less back pressure 176.25.

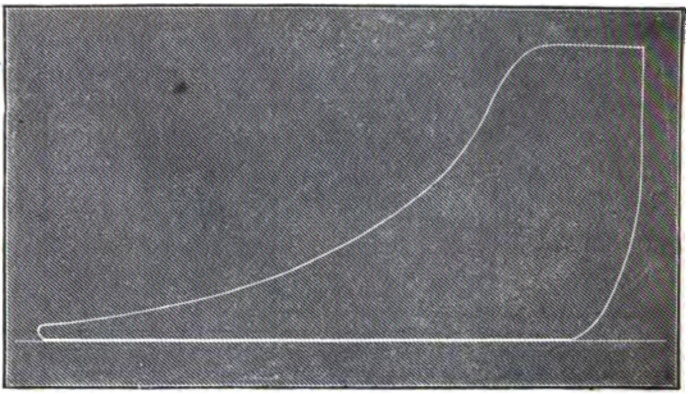


Steam, 76 lbs. Back pressure, 13 lbs. M. E. P., 41.6 lbs. I. H. P., 260. Less back pressure 178.75.

working at the power and speed indicated. Figure 2 C, shows 67 lbs. initial pressure; at point of cut-off the pressure is but 55 lbs., while the gauge within a short distance in main pipe indicated 78 lbs., showing the great loss of pressure by having pipes and steam ports so much out of proportion to size of cylinder. Again in diagram 1 C, the back pressure is 13 lbs., while the pressure in the main exhaust pipe was only 5 lbs. (the exhaust steam being used at that pressure for dyeing and heating), showing the enormous expenditure of steam and power. It is due to the Wheelock engine to say that this engine is very different from the "*Improved Wheelock*" of to-day, which in point of economy and uniform speed will compare quite favorably with any other.

By permission of Hill, Clarke & Co., Boston, several diagrams of the Hartford engines are given for the purpose of showing the workings of the engines under different loads and conditions. They are all 20x30 inch cylinder engine, running 130 revolutions per minute; also several diagrams of the Cummer engine with description.

Fig. 6.



MINIMUM ECONOMICAL LOAD.

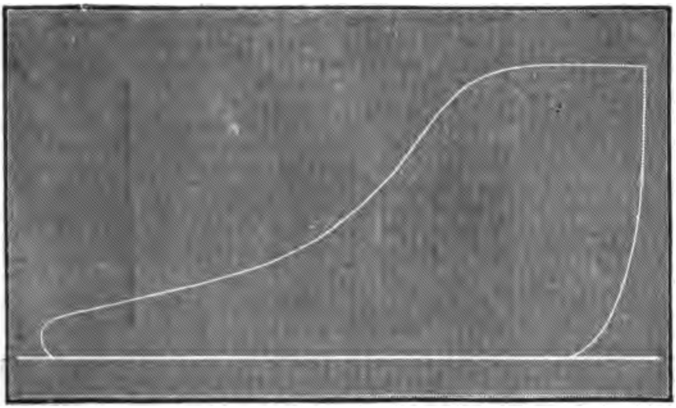
DATA.

Scale, 50. Mean effective pressure, 32. Terminal, 18.7. Steam per h. p. per hour, 18.8 lbs Horse power, 199.56.

The best practice of the present day demands a mean effective pressure of about 40 pounds for the best actual economy, and builders endeavor to adapt their engines as nearly as possible to that pressure.

While the principle of condensation has been generally adopted with large mill engines (except in cases where the exhaust steam can be used to better advantage for boiling, drying and heating), there are many places where the independent condenser can be used with a saving of fuel of 25 to 35 per cent. The motion is very smooth and easy, and can be varied by the engineer to suit the requirements of water, engine duty, etc. The cost of running is very light, as the pump runs mainly on its own vacuum. The quantity of water required for condensation is about twenty-five times the feed water for the boiler. This form of condenser is much safer, as the vacuum can be got up, and pipe and steam chest cleared of water

Fig. 7.



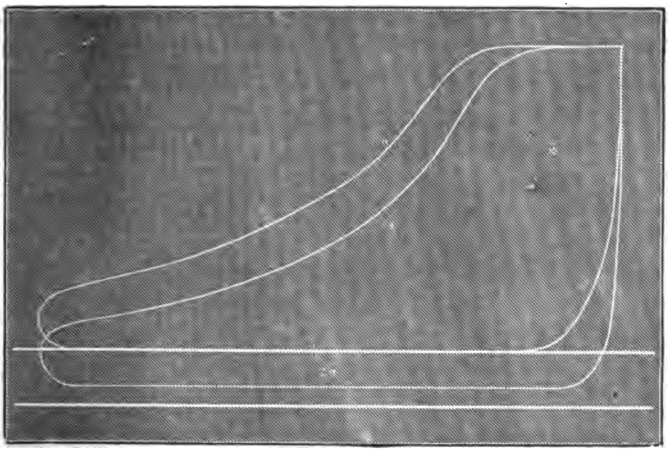
BEST ECONOMICAL LOAD.

DATA.

Scale, 50. Mean effective pressure, 41.11. Terminal, 24. Steam per h. p. per hour, 19.8 lbs. Horse power. 254.30.

before the engine is started. A very high vacuum can be got if desired, as shown in Fig. 8.

Fig. 8.



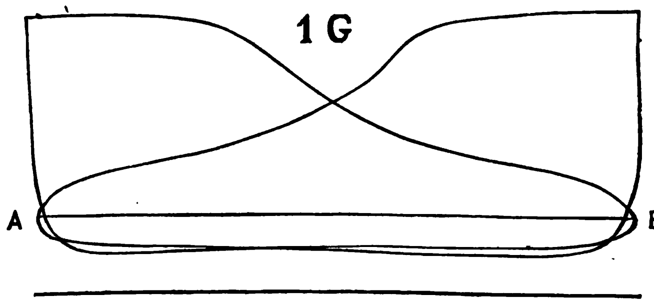
DATA.

Scale 50.		**Steam per h.p. per hour, high pressure,**	**19.6**
Mean effective pressure of both high and low pressure,	**47.5**	**" " " " " low "**	**14.5**
Terminal high pressure,	**28.5**	**Indicated horse power,**	**290.**
" low pressure,	**19.6**	**Economy due to condensing,**	**35 per ct.**

NOTE. [It will be noticed in these cards that the terms "Terminal Pressure" and "pounds of steam per horse power" are used. It has not been thought best in most of the diagrams introduced in this work to vary the calculations from the old plan of giving so much coal per horse power per hour, or so much work for the engine, without any special regard to the cost of the steam, supposing that the boilers have been run economically and steam furnished as cheaply as possible under the circumstances. Hence the terms "Clearance," "Terminal Pressure" and "Pounds of steam per Horse Power per hour" have been omitted (with most of the diagrams given and the necessary calculations attending their use, as not being very generally useful and more confusing). When the closest results are required for any special engine, the necessary calculations are introduced and expert engineers who desire, can go into the close calculations of clearances, terminals and pounds of steam per horse power per hour, if they wish.]

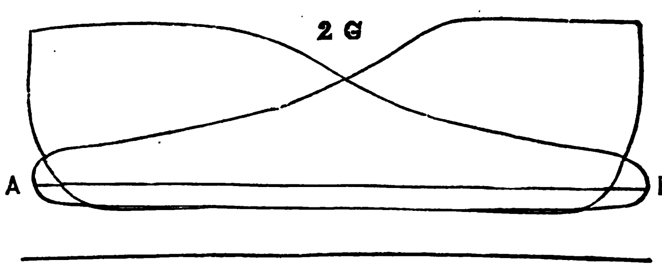
The following diagrams were taken from a Hartford engine, 20x30 inches, 119 revolutions per minute, having an independent condenser.

NOTE. [All the diagrams marked with figure and letter, are 50 scale, except two, the scale of which is mentioned.]



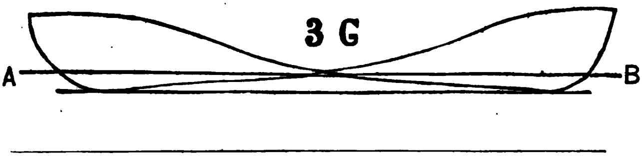
Steam, 63 lbs. Vacuum, 27 in. M. E. P., 41.4. I. H. P., 232.25.

Figure 1 G, shows the effect of the condenser with high steam and vacuum, working 232.25 horse power.



Steam, 50 lbs. Vacuum, 18 in. M. E. P., 34.4 lbs. I. H. P., 192.98.

Figure 2 G, medium steam and vacuum, working 192.98 horse power.

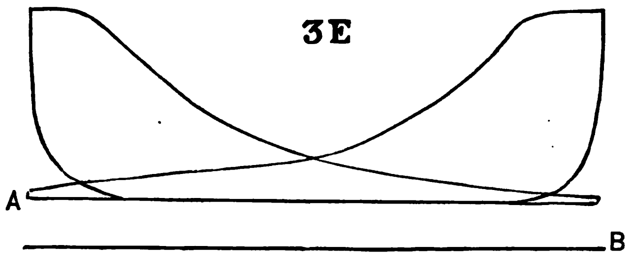


Steam, 22 lbs. Vacuum, 15 in. M. E. P., 5.6 lbs. I. H. P., 30.29.

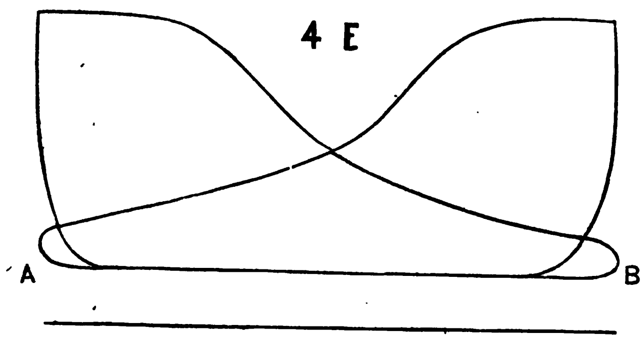
Figure 3 G, low steam and vacuum, working 30.29 horse power.

The three diagrams were taken within a few minutes of each other from the same engine, and the changed conditions were made for the purpose of ascertaining the power required to run the shafting alone; the ordinary work and about half of the electric lights and shafting, and the addition of the balance of electric lights. Fig. 1 G showing the whole.

Figures 3 and 4 E, are from the same engine working high pressure under different loads. Figure 3 E shows the ordinary work, and Fig. 4 E, the addition of electric lights.



Steam, 55 lbs. M. E. P., 18 lbs. I. H. P., 100.98 lbs.

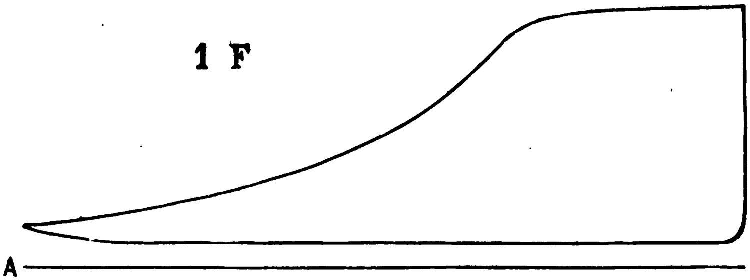


Steam, 72 lbs. M. E. P., 37.8 lbs. I. H. P., 212.05 lbs.

The change from low to high pressure was necessary to make during the middle of the day for several days, on account of low water at that time, while the engine was running and doing its work. And not the slightest variation in speed could be detected, showing the great advantage of this arrangement.

Condensers owe their efficiency to the fact that they create a partial vacuum on the exhaust side of the piston and thus reduce back pressure in

proportion to the perfection of the vacuum. Atmospheric pressure, such as non-condensing engines work against, amounts to 14.7 lbs. per square inch. From 11 to 13 lbs. of this may be removed by means of a condenser. and is just so much added to the mean effective pressure, without any additional cost, except the small amount of power required to operate the air pump, as heretofore stated. Since a condenser will thus add so largely to the power and economy of the engine with but slight additional outlay, its use is recommended wherever a sufficient supply of good water can be obtained for injection, or where exhaust steam is not required for boiling and heating. As much of the discharge water from the condenser as may be required for feed, can be used, as the temperature would be about 110° F. In cases where a large amount of power is steadily required, the compound condensing engine is strongly recommended. Have the steam cylinders provided with casing for live steam, which makes the most efficient jacket known. Engines arranged with all the improvements specified in this work, have been known to work with the small amount of 1⅝ lbs. of coal per horse power per hour.



Steam, 77 lbs. Back pressure, 7.17 lbs. M. E. P., 40.6 lbs. I. H. P., 489.23 lbs. Less back pressure, 403.67 lbs.

Figure 1 F is from a 34¼x84 inch upright Corliss beam engine, 31 revolutions per minute. Having been in use more than twenty years, it is good to-day for many kinds of work.

TABLE.

To facilitate the measurement of diagrams, etc., or making other calculations, the following table of fractions of an inch, reduced to decimals will be found convenient:—

Com. Frac.	Decimal.	Com. Frac.	Decimal.	Com. Frac.	Decimal.	Com. Frac.	Decimal.
$\frac{1}{32}$	.0312	$\frac{9}{32}$	.2812	$\frac{17}{32}$	.5312	$\frac{25}{32}$	.7812
$\frac{1}{16}$	.0625	$\frac{5}{16}$	.3125	$\frac{9}{16}$	.5625	$\frac{13}{16}$	.8125
$\frac{3}{32}$	.0937	$\frac{11}{32}$	.3437	$\frac{19}{32}$	.5977	$\frac{27}{32}$	.8437
$\frac{1}{8}$	.1250	$\frac{3}{8}$	.3750	$\frac{5}{8}$	.6250	$\frac{7}{8}$	.8750
$\frac{5}{32}$	.1562	$\frac{13}{32}$	.4062	$\frac{21}{32}$	.6562	$\frac{29}{32}$	.9062
$\frac{3}{16}$	.1875	$\frac{7}{16}$	.4375	$\frac{11}{16}$	.6875	$\frac{15}{16}$	.9375
$\frac{7}{32}$	.2187	$\frac{15}{32}$	.4687	$\frac{23}{32}$	.7187	$\frac{31}{32}$	.9687
$\frac{1}{4}$	.2500	$\frac{1}{2}$	.5000	$\frac{3}{4}$	.7500	$\frac{32}{32}$	1.0000

TABLE.

Showing the elastic force, temperature, and volume of steam, at temperatures from 32° to 387.3° Fahrenheit, varying by 5° of temperature up to the boiling point, then by ½ lbs. of pressure on the square inch up to 25 lbs., then by lbs. of pressure up to 85 lbs., and then by 5 lbs. of pressure up to 200 lbs.

Elastic force in		Temperature.	Volume.	Elastic force in		Temperature.	Volume.
Inches of Merc'y.	Lbs. per Sq. inch.			Inches of Merc'y.	Lbs. per Sq. inch.		
.200	.098	32.	187407	31.62	15.5	214.5	1618
.221	.108	35.	170267	32.64	16.	216.3	1573
.263	.129	40.	144529	33.66	16.5	218.	1530
.316	.155	45.	121483	34.68	17.	219.6	1488
.375	.184	50.	103350	35.7	17.5	221.2	1440
.443	.217	55.	88388	36.72	18.	222.7	1411
.524	.257	60.	75421	37.74	18.5	224.2	1377
.616	.302	65.	64762	38.76	19.	225.6	1343
.721	.353	70.	55862	39.78	19.5	227.1	1312
.851	.417	75.	47771	40.80	20.	228.5	1281
1.	.49	80.	41031	41.82	20.5	229.9	1253
1.17	.573	85.	35393	42.84	21.	231.2	1225
1.36	.666	90.	30425	43.86	21.5	232.5	1199
1.58	.774	95.	26686	44.88	22.	233.8	1174
1.86	.911	100.	22873	45.90	22.5	235.1	1150
2.04	1.	103.	20958	46.92	23.	236.3	1127
2.18	1.068	105.	19693	47.94	23.5	237.5	1105
2.53	1.240	110.	16667	48.96	24.	238.7	1084
2.92	1.431	115.	14942.	49.98	24.5	239.9	1064
3.33	1.632	120.	13215	51.	25.	241.	1044
3.79	1.857	125.	11723	53.04	26.	243.3	1007
4.34	2.129	130.	10328	55.08	27.	245.5	973
5.00	2.450.	135.	9036	57.12	28.	247.6	941
5.74	2.813	140.	7938	59.16	29.	249.6	911
6.53	3.100	145.	7040	61.2	30.	251.6	883
7.42	3.636	150.	6243	63.24	31.	253 6	857
8.40	4.116	155.	5559	65.28	32.	255.5	833
9.46	4 635	160.	4976	67.32	33.	257.3	810
10.68	5.23	165.	4443	69.36	34.	259.1	788
12.13	5.94	170.	3943	71.4	35.	260.9	767
13.62	6.67	175.	3538	73.44	36.	262.6	748
15.15	7.42	180.	3208	75.48	37.	264.3	729
17.	8.33	185.	2879	77.52	38.	265.9	712
19.	9.31	190.	2595	79.56	39.	267.5	695
21.22	10.4	195.	2342	81.6	40.	269.1	679
23.64	11.58	200.	2118	83.64	41.	270.6	664
26.13	12.8	205.	1932	85.68	42.	272.1	649
28.84	14.13	210.	1763	87.72	43.	273.6	635
29.41	14.41	211.	1730	89.76	44.	275.	622
30.	14.7	212.	1700	91.8	45.	276.4	610
30.6	15.	212.8	1669	93.84	46.	277.8	598

Elastic force in		Tempera-ture.	Volume.	Elastic force in		Tempera-ture.	Volume.
Inches of Merc'y.	Lbs. per Sq. inch.			Inches of Merc'y.	Lbs. per Sq. inch.		
95.88	47.	279.2	586	159.14	78.	314.	370
97.92	48.	280.5	575	161.18	79.	314.9	366
99.96	49.	281.9	564	163.22	80.	315.8	362
102.	50.	283.2	554	165.26	81.	316.7	358
104.04	51.	284.4	544	167.3	82.	317.6	354
106.08	52.	285.7	534	169.34	83.	318.4	350
108.12	53.	286.9	525	171.38	84.	319.3	346
110.16	54.	288.1	516	173.42	85.	320.1	342
112.2	55.	289.3	508	183.62	90.	324.3	325
114.24	56.	290.5	500	193.82	95.	328.2	310
116.28	57.	291.7	492	203.99	100.	332.	295
118.32	58.	292.9	484	214.19	105.	335.8	282
120.36	59.	294.2	477	224.39	110.	339.2	271
122.4	60.	295.6	470	234.59	115.	342.7	259
124.44	61.	296.9	463	244.79	120.	345.8	251
126.48	62.	298.1	456	254.99	125.	349.1	240
128.52	63.	299.2	449	265.19	130.	352.1	233
130.56	64.	300.3	443	275.39	135.	355.	224
132.6	65.	301.3	437	285.59	140.	357.9	218
134.64	66.	302.4	431	295.79	145.	360.6	210
136.68	67.	303.4	425	306.	150.	363.4	205
138.72	68.	304.4	419	316.19	155.	366.	198
140.76	69.	305.4	414	326.39	160.	368.7	193
142.8	70.	306.4	408	336.59	165.	371.1	187
144.84	71.	307.4	403	346.79	170.	373.6	183
146.88	72.	308.4	398	357.	175.	376.	178
148.92	73.	309.3	393	367.2	180.	378.4	174
150.96	74.	310.3	388	377.1	185.	380.6	169
153.02	75.	311.2	383	387.6	190.	382.9	166
155.06	76.	312.2	379	397.8	195.	384.7	161
157.1	77.	313.1	374	408.	200.	387.3	158

HYPERBOLIC LOGARITHMS.

To Find the Mean Pressure by Hyperbolic Logarithms.

Rule.—Divide the length of the stroke by the length of the space into which the steam is admitted; find in the table the logarithm of the number nearest to that of the quotient, to which add 1. The sum is the ratio of the gain.

Example.—Suppose the steam to enter the cylinder at the pressure of 40 lbs. per square inch, and to be cut off at ¼ of the length of the stroke; what is the mean pressure, the stroke being 10 feet?

$$10 \div 2.5 = 4. \quad \text{Hyp. log. of } 4 = 1.38629 + 1 = 2.38629.$$

$$\text{Then, as } 4 : 2.38629 :: 40 : 23.8629 \text{ lbs.}$$

TABLE

Of Hyperbolic Logarithms.

No.	Logarithm.	No.	Logarithm.	No.	Logarithm.	No.	Logarithm.
1.25	.22314	4.	1.38629	6.75	1.90954	12.	2.48490
1.5	.40546	4.25	1.44691	7.	1.94591	13.	2 56494
1.75	.55961	4.5	1.50507	7.25	1.98100	14.	2.63905
2.	.69314	4.75	1.55814	7.5	2.01490	15.	2.70805
2.25	.81093	5.	1.60943	7.75	2.04769	16.	2.77258
2.5	.91629	5.25	1.65822	8.	2.07944	17.	2.83321
2.75	1.01160	5.5	1.70474	8.5	2.14006	18.	2.89037
3.	1.09861	5.75	1.74919	9.	2.19722	19.	2.94443
3.25	1.17865	6.	1.79175	9.5	2.25129	20.	2.99573
3.5	1.25276	6.25	1.83258	10.	2.30258	21.	3.04452
3.75	1.32175	6.5	1.87180	11.	2.39789	22.	3.09104

TABLE

Of Steam Used Expansively.

Initial Pressure, lbs. per square inch.	Average Pressure of steam in pounds per square inch for the whole stroke.					
	Portion of stroke at which steam is cut off.					
	$\frac{3}{4}$	$\frac{5}{8}$	$\frac{1}{2}$	$\frac{3}{8}$	$\frac{1}{4}$	$\frac{1}{8}$
5	4.8	4.6	4.2	3.7	2.9	1.9
10	9.6	9.1	8.4	7.4	5.9	3.8
15	14.4	13.7	12.7	11.1	8.9	5.7
20	19.2	18.3	16.9	14.8	11.9	7.6
25	24.1	22.9	21.1	18.5	14.9	9.5
30	28.9	27.5	25.4	22.2	17.9	11.5
35	33.8	32.1	29.6	25.9	20.8	13.4
40	37.5	36.7	33.8	29.6	23.8	15.4
45	43.4	41.3	38.1	33.3	26.8	17.3
50	48.2	45.9	42.3	37.0	29.8	19.2
60	57.8	55.1	50.7	44.5	35.7	23.1
70	67.4	64.3	59.2	52.4	41.7	26.9
80	77.1	73.5	67.7	59.3	47.7	30.8
90	86.7	82.6	76.1	66.7	53.6	34 6
100	96.3	91.8	84.6	74.1	59.6	38.4
110	106.0	101.0	93.1	81 5	65.6	42.5
120	115.2	110.2	101.5	89.4	71.5	46.1
130	125.4	119.1	110.0	95.3	77.5	50.0
140	134.9	128.6	118.5	103.8	83.3	53.8
150	144.7	137.8	126.4	111.2	89.4	57.7
160	153.6	147.0	135.4	118.2	95.4	61.5
180	173.5	164.6	152.3	132.9	107.3	69.2
200	192.7	183.7	169.3	148.3	119.3	76.9

TABLE

Exhibiting the Expansive Force and Various Conditions of Steam Under Different Degrees of Temperature.

Degrees of heat.	Pressure in atmospheres.	Density. Water as 1.	Volume. Water as 1.	Spec. gravity. Air as 1.	Wgt. of a cubic ft. in grains.
212.	1	.00059	1694	.484	254
250.5	2	.00110	909	.915	483
276.	3	.00160	625	1.330	700
293.8	4	.00210	476	1.728	910
308.	5	.00258	387	2.120	1110
359.	10	.00492	203	3.970	2100
418.5	20	.00973	106	7.440	3940

[An atmosphere is 14 7-10 lbs. to the square inch.]

NOTE.—By the above table it is seen that any given quantity of steam having a temperature of 212° F., occupies a space, under the ordinary pressure of the atmosphere, 1694 times greater than it occupied when as water, in a natural state. It exerts a mechanical force, consequently, on a given surface, 1694 times greater than the weight or force of the atmosphere resting on the same surface—a force of 24902 lbs. on each square inch. A force, if we consider the volume as so many cubic inches, equal to the raising of 2087 lbs. twelve inches high, by a quantity of steam less than a cubic foot, heated only to the temperature of boiling water, and weighing but 248 grains, and that, too, the product of a single cubic inch of water!

The mean pressure of the atmosphere at the earth's surface, is equal to the weight of a column of mercury 26.9 inches in height, or to a column of water 33.87 feet in height,=2116.8 lbs. per square foot, or 14.7 lbs. per square inch. Its density above the earth is uniformly less as its altitude is greater, and its extent is not above 50 miles—its mean altitude is about 45 miles; at 44 miles it ceases to reflect light. Were it of uniform density throughout, and of that at the surface, its altitude would be but 5¼ miles. Its weight is to pure water of equal temperature and volume, as 1 to 829. It revolves with the earth, and its average humidity, at 40° of latitude, is 4 grains per cubic foot. Its weight at 60°, b. 30, compared with an equal bulk of pure water at 40°, b. 30, is as 1 to 830.1.

TABLE

Of the Density of Steam Under Different Pressures.

Atmosphere.	Density.	Volume.	Atmosphere.	Density.	Volume.	Atmosphere.	Density.	Volume.
1	.00059	1694	5	.00258	387	12	.00581	172
2	.00110	909	6	.00306	326	14	.00670	149
3	.00160	625	8	.00399	250	16	.00760	131
4	.00210	476	10	.00492	203	18	.00849	117

The volumes are not direct, in consequence of the increase of heat.

COMPUTATION TABLE. [*See Page 62.*]

P	W	P	W	P	W	P	W	P	W	P	W
3	39.10	23	34.70	43	33.42	63	32.70	83	32.18	103	31.77
4	38.47	24	34.61	44	33 38	64	32.67	84	32.16	104	31.75
5	37.95	25	34.53	45	33 34	65	32 64	85	32.14	105	31.73
6	37.54	26	34.45	46	33.30	66	32.61	86	32.12	106	31.71
7	37.22	27	34.37	47	33.26	67	32.58	87	32.09	107	31.69
8	36.93	28	34.29	48	33.22	68	32.55	88	32.07	108	31.67
9	36.67	29	34.22	49	33.18	69	32.52	89	32.05	109	31 65
10	36.44	30	34.15	50	33.14	70	32.49	90	32.03	110	31.63
11	36 24	31	34.08	51	33.10	71	32.46	91	32.00	111	31.61
12	36.06	32	34.01	52	33.06	72	32 43	92	31.98	112	31 59
13	35.89	33	33.95	53	33.02	73	32.40	93	31.96	113	31.57
14	35.73	34	33.89	54	32.98	74	32.38	94	31 94	114	31.55
15	35.59	35	33.83	55	32.94	75	32.36	95	31.92	115	31.54
16	35.46	36	33.77	56	32.91	76	32.34	96	31.90	116	31.53
17	35.34	37	33.72	57	32.88	77	32.32	97	31.88	117	31.52
18	35.22	38	33.67	58	32.85	78	32.30	98	31.86	118	31.51
19	35.10	39	33.62	59	32.82	79	32.27	99	31.84	119	31.50
20	34.99	40	33.57	60	32.79	80	32 25	100	31.82	120	31.49
21	34.89	41	33.52	61	32.76	81	32.23	101	31.80	121	31.48
22	34.79	42	33.47	62	32.73	82	32.20	102	31.78		

CISTERNS.

CAPACITY OF CISTERNS IN U. S. GALLONS, FOR EACH 10 INCHES IN DEPTH.

2	feet diameter	19.5	8	feet diameter	313.33
2½	"	30.6	8½	"	353.72
3	"	44.06	9	"	396 56
3½	"	59.97	9½	"	461.40
4	"	78.33	10	"	489.20
4½	"	99.14	11	"	592 40
5	"	122.40	12	"	705.
5½	"	148.10	13	"	827.4
6	"	176.25	14	"	959 6
6½	"	206.85	15	"	1101.6
7	"	239.88	20	"	1958.4
7½	"	275.40	25	"	3059.9

HORSES.

The following information in relation to horses will be found useful in reference to the application of steam:—

A *horse* travels 400 yards, at a walk, in 4½ minutes; at a trot, in 2 minutes; at a gallop, in 1 minute.

Average weight=1000 lbs. each.

A *horse* carrying a soldier and his equipments (say 225 lbs.), travels 25 miles in a day (8 hours).

A *draught horse* can draw 1600 lbs. 23 miles a day, weight of carriage included.

The ordinary work of a horse may be stated at 22.500 lbs., raised 1 foot in a minute, for 8 hours a day.

In a *horse mill*, a horse moves at the rate of 3 feet in a second. The diameter of the track should not be less than 25 feet.

A *horse power* in machinery is estimated at 33.000 lbs., raised 1 foot in a minute; but as a horse can exert that force but 6 hours a day, one machinery horse power is equivalent to that of 4.4 horses.

The strength of a horse is equivalent to that of five men.

TABLE

OF MEAN EFFECTIVE AND TERMINAL PRESSURES.

PRESSURES.		Point of Cut-Off.	Rate of Expan.	Mean pressure through't Stroke.	Back Pressure		M. E. P.		Terminal pressure above Vacuum.
Above Atmos.	Above Vac'um				Non-Cond'g.	Cond'-ing.	Non-Cond's'g.	Condens-ing.	
50	65	1/5	5	33.77	16	4	17.77	29.77	12.94
		1/4	4	38.56	16	4	22.56	34.56	16.18
		3/8	2.66	48.14	16	4	32.14	44.14	24.26
		1/2	2	54.74	16	4	38.74	50.74	32.35
55	70	1/5	5	36.38	16	4	20.38	32.38	13.94
		1/4	4	41.54	16	4	25.54	37.54	17.43
		3/8	2.66	51.86	16	4	35.86	47.86	26.14
		1/2	2	58.97	16	4	42.97	54.97	34.85
60	75	1/5	5	38.99	16	4	22.99	34.99	14.94
		1/4	4	44.52	16	4	28.52	40.52	18.68
		3/8	2.66	55.58	16	4	39.58	51.58	28.01
		1/2	2	63.20	16	4	47.20	59.20	37.35
65	80	1/5	5	41.60	16	4	25.60	37.60	15.94
		1/4	4	47.50	16	4	31.50	43.50	19.93
		3/8	2.66	59.30	16	4	43.30	55.30	29.89
		1/2	2	67.48	16	4	51.48	63.48	39.85
70	85	1/5	5	44.21	16	4	28.21	40.21	16.94
		1/4	4	50.48	16	4	34.48	46.48	21.18
		3/8	2.66	63.02	16	4	47.02	59.02	31.76
		1/2	2	71.66	16	4	55.66	67.66	42.35
75	90	1/5	5	46.82	16	4	30.82	42.82	17.94
		1/4	4	53.46	16	4	37.46	49.46	22.43
		3/8	2.66	66.74	16	4	50.74	62.74	33.64
		1/2	2	75.89	16	4	59.89	71.89	44.85
80	95	1/5	5	49.43	16	4	33.43	45.43	18.94
		1/4	4	56.44	16	4	40.44	52.44	23.68
		3/8	2.66	70.46	16	4	54.46	66.46	35.51
		1/2	2	80.12	16	4	64.12	76.12	47.35
85	100	1/5	5	52.04	16	4	36.04	48.04	19.94
		1/4	4	59.42	16	4	43.42	55.42	24.93
		3/8	2.66	74.18	16	4	58.18	70.18	37.39
		1/2	2	84.35	16	4	68.35	80.35	49.85
90	105	1/5	5	54.65	16	4	38.65	50.65	20.94
		1/4	4	62.40	16	4	46.40	58.40	26.18
		3/8	2.66	77.90	16	4	61.90	73.90	39.26
		1/2	2	88.58	16	4	72.58	84.58	52.35
95	110	1/5	5	57.26	16	4	41.26	53.26	21.94
		1/4	4	65.38	16	4	49.38	61.38	27.43
		3/8	2.66	81.62	16	4	65.62	77.62	41.14
		1/2	2	92.81	16	4	76.81	88.81	54.85
100	115	1/5	5	59.87	16	4	43.87	55.87	22.94
		1/4	4	68.36	16	4	52.36	64.36	28.68
		3/8	2.66	85.34	16	4	69.34	81.34	43.01
		1/2	2	97.04	16	4	81.04	93.04	57.35

NOTE.—In order to get rid of an inconvenient fraction in the second column, the pressures above the atmospheric are given in round numbers at 15 lbs. instead of 14.7 lbs. The calculations are all made with the latter and not the former figures.—[Cummer Engine Co.

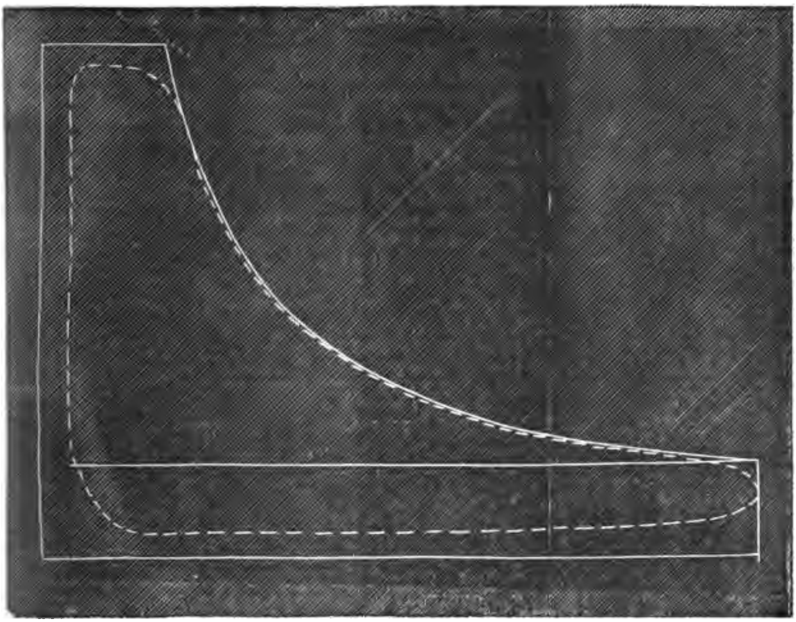
INDICATOR DIAGRAMS FROM CUMMER ENGINE.

The application of the indicator to an engine is really a scientific experiment, and should be undertaken with a degree of care and precaution against error such as men of science adopt; the conclusions based upon the diagrams must also be judiciously made. While we are not of those who unduly exalt the office of the indicator to perform all sorts of impossible things, we do claim, and know, that when intelligently applied, the results are perfectly reliable, and are very valuable. There is no other way by which we may know positively that the valves have been properly set, and that the steam is acting to the best advantage, except by taking an indicator diagram from the engine, and correctly interpreting the various lines; nor can we ascertain in any other way with a reasonable degree of certainty what power is being developed by the engine, or form any idea of how closely the actual power approaches the ordinary rating.

In these diagrams which follow, unless otherwise stated, the dotted portion is the actual figure traced by the indicator; and the full line is the theoretical diagram of steam expanding from boiler pressure, with a cut-off equal to the given cut-off and clearance added, down to terminal pressure —pressures being measured from the atmospheric line in non-condensing engines, and from line of perfect vacuum in condensing engines.

Whenever the scale of the diagram is not given, it is to be understood that the original was reduced by photography, in order to make the wood cut of a suitable size for our pages; this reduction does not, of course, af-

Fig. 9.

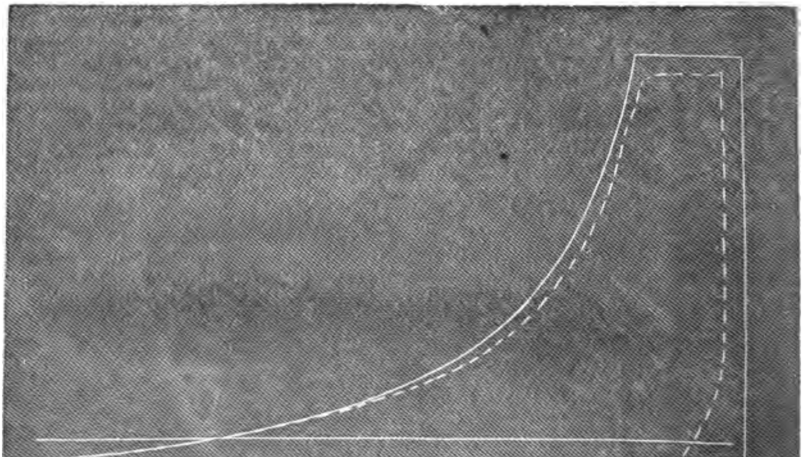


fect the truth of the diagram, since everything preserves the same proportion as before, but the diagram cannot be measured by the usual scale.

Fig. 9, scale 30 lbs., was taken from a 20 x 36 condensing engine, revolutions 73, steam pressure in boiler 65 pounds. The load on this engine is too light for economy. but the diagram is a good one; the admission line and steam line are good; the expansion line coincides very closely with the theoretical curve, and there is a free exhaust and excellent line of counter pressure. The compression might begin a little earlier with advantage.

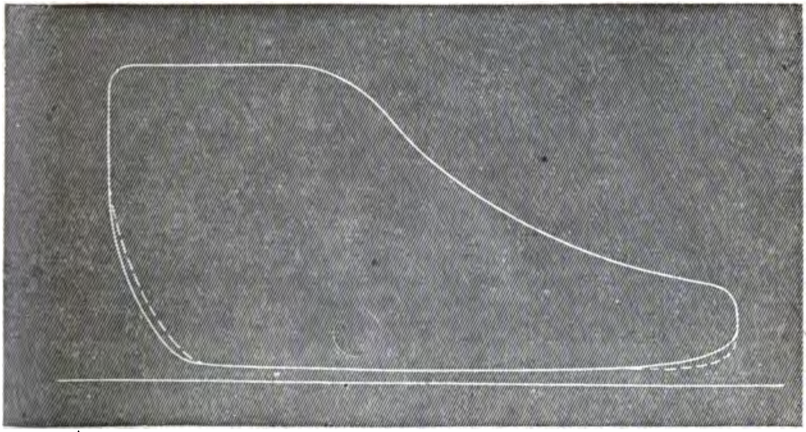
Fig. 10, scale 30 lbs., is a diagram from a 22x42 automatic condensing engine, revolutions 75, steam pressure 60 pounds; this is also taken with a light load. The point of cut-off is well defined, and expansion and exhaust lines are good; the line of counter pressure runs nearly parallel with the line of perfect vacuum, and about four pounds above it. Here we have a better compression than in No. 9.

Fig. 10.



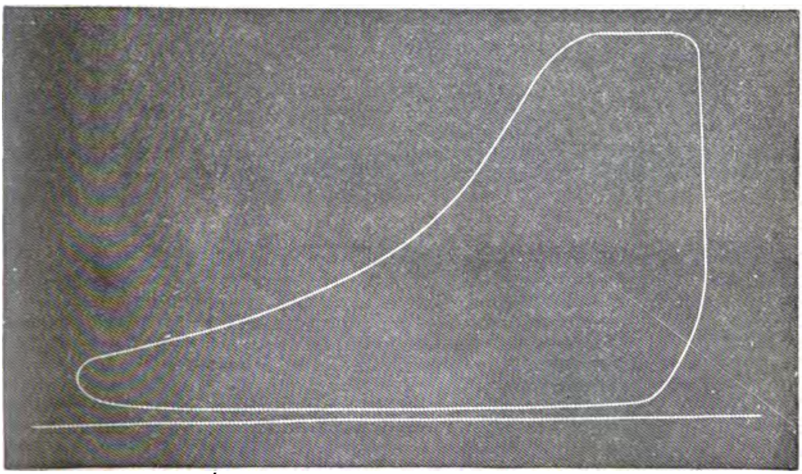
Our arrangement of separate exhaust valves is such that we can always set them to secure any desired release or compression. It is important to have a free exhaust without allowing release to take place too early; at the same time compression must be arranged so that steam in the clearance space may be compressed to proper pressure at the beginning of each stroke. Owing to the much lower counter pressure in condensing engines, it is more difficult to secure suitable compression than with non-condensing engines; we have to commence to cushion earlier, and wish to do so without having to exhaust any earlier. In most other engines an early compression means an early

Fig. 11.



release, but in our engine these two points can be adjusted independently, as we shall now show. When a valve motion is designed, we always give sufficient travel, which, while small, still allows a certain range for adjustment, and, in consequence of having valves at each end of the cylinder, which are independent of each other, we have practically an adjustable amount of lap. Suppose that we have the steam admission and exhaust release arranged to our satisfaction, but that it is desired to give more compression, instead of deranging two things to effect an improvement

Fig. 12.



in one point, we can bring them all to be just as we desire. Thus we can shift our main eccentric so as to give an earlier closure to the exhaust valve for our desired compression, and give more lap, so as to preserve the same lead as before, and therefore the same release. Nor do we really disturb the main valve, because it may be moved so as to have more lap and keep the same lead or opening at the commencement of a stroke as before. while its earlier closure does not affect the working, because we have allowed ourselves a limit of movement for adjustment. It will be apparent how easily and accurately our valves may be set, the change may be made if a non-condensing engine is to be worked as a condensing engine and still run smoothly, or to secure such results as the indicator shows to be desirable.

To illustrate these points we have inserted diagrams from one of our 14x30 Class C engines. In Fig. 11 it will be seen that the release is not early enough, and that in consequence of this, the back pressure at the commencement of the return stroke is much too high. This shows the effect of an improper valve setting; to remedy this defect, the main eccentric should be advanced slightly; this gives the exhaust valve an earlier opening, and produces an exhaust line and line of back pressure, as shown by the dotted curved line at this portion of the figure; at the same time the compression begins a little earlier, as shown by the dotted line at the point of compression. To preserve the same linear lead for the main valves, as before, we then spread them so as to give enough lap to compensate for the angular advance. This causes an earlier cut-off for the main valve, but not enough earlier than is within the limits assigned to the cut-off valve.

If we had wished to have an earlier release, and retain the same compression line, this could be accomplished by moving the exhaust valves towards each other, the same distance that the main steam valves had been spread, or moved apart from each other.

The line of back pressure in the diagram is nearly four pounds above the atmospheric line, whereas it should not be more than half a pound above this line, as shown in Fig. 13. This defect was in consequence of an improper connection with the heater, and the diagram, in contrast to Fig. 13, shows how a good engine may be given imperfect working, if those who attend to the erecting and valve setting do not perform their work properly, and do not make use of the indicator to correct any error or oversight that may occur. The two diagrams, Figs. 11 and 12 from the 14x30 engine, show the benefit to be derived from high pressure steam and expansion at an economical rate, compared with steam of lower pressure allowed to follow further. In Fig. 11, scale 50 lbs., the boiler pressure is about 85 lbs.; the point of cut-off about $\frac{3}{8}$ stroke, and the M. E. P. is 51 lbs., which gives, at 112 revolutions, 133.2 horse power. The terminal pressure 39.7 lbs., is high; this pressure representing the steam consumed and the mean pressure above vacuum representing the gross work done in a stroke, if we divide the latter figure by the terminal pressure, we obtain a result which shows the gain by expansion: thus, $69.7 \div 39.7 = 1.75$, the gain by expansion with 85 lbs. steam cut-off at $\frac{3}{8}$ stroke. Fig 12, scale 50 lbs., is a card from the same engine only using steam of 102 lbs., and cutting off at $\frac{1}{4}$, instead of at $\frac{3}{8}$; here the M. E. P. is 49.29 lbs., yielding, at 112 revolutions, 128.62 horse power. We have a lower terminal pressure, which is 32.7 lbs. Dividing as before, the mean absolute pressure, by the terminal pressure, we get $67.99 \div 32.7 = 2.08$, the gain by expansion in this case.

This gain compared with the former figure, and a comparison of the horse powers calculated from the two cards, shows that with a cut-off at $\frac{1}{4}$ stroke, with steam at 102 lbs., we obtain within four per cent, of the power given by steam at 85 lbs. cut-off at $\frac{3}{8}$ stroke; and, that we thus secure practically the same power with about 17% less steam consumption. The

boiler used with this engine is 64″ diameter x16 feet long, with 50 tubes four inches in diameter; it is such a boiler as we furnish and consider to be proper for one of our 14x30 Class C engines. A comparison of the horse power developed by the engine with the power ratings in our tables will show that our engines and boilers may be fully relied upon to yield an economical power beyond our ratings. It is to be remembered that in these diagrams the back pressure is high; this was a fault in the connection with the heater, as already explained, and was very easily remedied. But if the difficulty had not existed, the same steam, taken from the boiler, and which is indicated by the diagrams, would have yielded 10 additional effective horse-power, instead of being uselessly expended in overcoming back pressures; and the duty that would have been economically obtained from this engine and boiler is, therefore, entitled to be increased from 128.6 horse power to 138.6 horse power. The boiler fired quite easily, and without crowding in any way, at the time these cards were taken. These two cards, illustrating so well several points of interest and importance, we have gone into the subject a little more thoroughly, so that the public may know that we have given these important and vital matters our careful, intelligent and practical consideration; and, also, to show that the power ratings given by us, both for our engines and boilers, are sustained by actual and solid results.

Fig. 18.

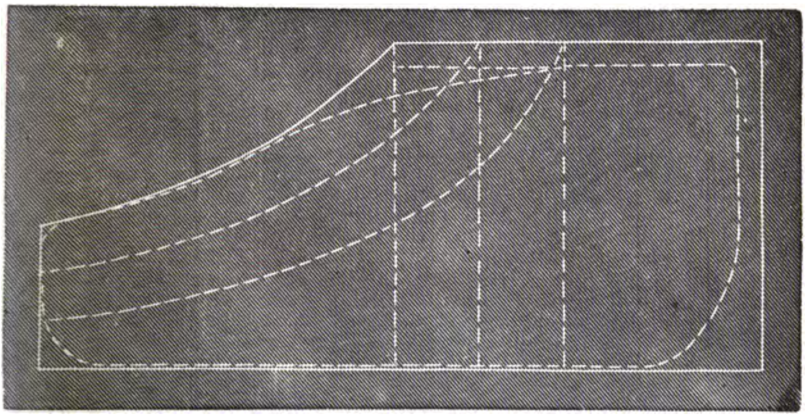


Fig. 18 is from an 18x36 Automatic Cummer engine, the cut-off is at ½ stroke, boiler pressure 87 lbs., a higher pressure being used in winter, initial pressure 81 lbs., revolutions 100, horse power developed 300 horse power.

This engine is used to drive a saw mill. The full power required by the mill varies from 250 to 325 horse power, according to the size of the timber and its condition, whether frosty or otherwise. From 60 to 65 horse power is absorbed by the friction of the mill and the smaller saws; the latter consist of one gang edger, one gang bolter and one gang lath mill, and this is the only constant load upon the engine. The large 6 foot circular saw makes 650 revolutions per minute with a steam feed which advances the carriage 13½ inches for each revolution of the saw. When in

the cut, the large circular absorbs 150 to 250 horse power, which is in addition to the power required by the mill. and, the moment the saw is out of the cut the load is instantly reduced to the friction load of 60 to 65 horse power; this sudden variation of power occurs several times per minute. There is an interval of time, however, when a new log is being put on the carriage, where the engine might race if not controlled by the governor, but the governor holds the engine so closely to its normal speed that there are no perceptible variations in its revolutions with any load that may vary from the friction load to that at half stroke, and from the friction load to ⅞ stroke, the variations do not exceed four revolutions. Our expert and the owners of the engine assert that up to half stroke the variation was so slight that they could not count close enough to detect with certainty a variation of even one revolution from standard speed. This engine is working to maximum capacity, and Fig. 13, which shows the action of the steam under a full load we consider to be an unusually good one. The steam line is parallel to the atmospheric line up to ¼ stroke, beyond this there is shown a slight wire-drawing up to the point of cut-off at ½ stroke. The loss of pressure from this cause is but very little, and is more apparent than real; it amounts to but 1¼ lbs. for a whole stroke, which is more than compensated for by other advantages, as will appear later on. This card shows a good expansion line and a remarkably good exhaust line, the large quantity of steam in the cylinder is exhausted as quickly and freely as with a cut-off very early in the stroke. The line of counter pressure shows very little resistance and the compression line and admission line are both good. For the purpose of discussing some of the features of our valve system, we have drawn in dotted lines upon the diagram the theoretical curves for ¼ and ⅜ cut-off, and there is shown the completed figure for each of these points: referring now to the diagram it will be seen that up to ¼ stroke there is no diminution in the height of the steam line, and that at ⅜ cut-off the loss of pressure is but very slight, amounting to only ¼ of a pound for a whole stroke. Our economical range for expansion is from 1-5 to ⅜ cut-off, the best economy being had for a cut-off at ¼ stroke; at this point, and also for 1-5 and under, there is no loss of pressure whatever, and at ⅜ stroke it amounts in this case to only ¼ of a pound which is inconsiderable. For a cut-off at ½ stroke there is the reduction in pressure such as shown by the diagram, and for ⅞ there would be somewhat more; now although we could make our ports and valves of such a size that there would be no wire-drawing whatever, even when following as far as ⅞ stroke, yet increasing the size and travel of our valves would increase the friction very much, and we have aimed to keep this as low as possible. So that it is a matter of free choice, and not of necessity, which has led us to submit to a little wire-drawing, after passing the economical range of expansion, in order to secure the great advantage of a plain, unbalanced valve moving with but very little friction, and it will be seen that in effect we sacrifice nothing, because our engines are designed to work economically with a cut-off varying from 1-5 to ⅜, and within these limits there is no appreciable loss. Beyond ⅜ cut-off the engine should not be called upon to go for regular working, for, while a cut-off later than ⅜ yields more power, it does not give enough expansion for good economy and an engine should only occasionally be called upon to exert its full capacity; it should be large enough to perform its regular work with a cut-off varying from 1-5 to ⅜. For an expansion within this range, our valves and port proportions are such that our engines have been shown to yield an exceptionally high economy, placing them in the very foremost rank of economical steam-users, and this without encumbering them with the unnecessary and injurious friction and wear inseparable from large valve and frictional surfaces. Our long and watch-

ful experience enables us to decide upon these proportions without erring on either side, as is demonstrated by our diagrams and the working of our engines.

Fig. 14.

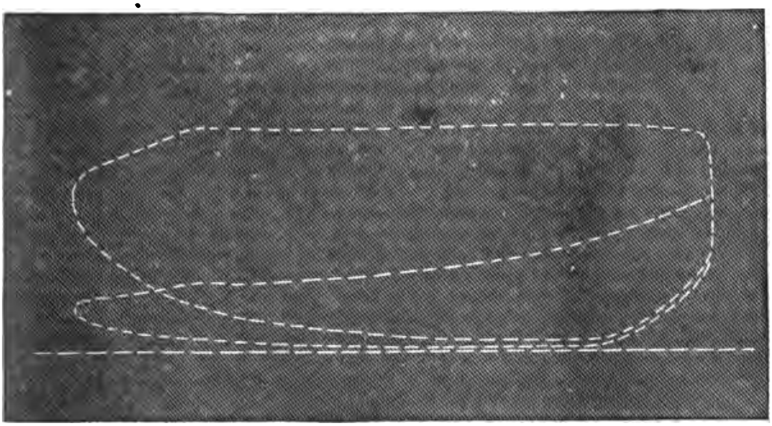
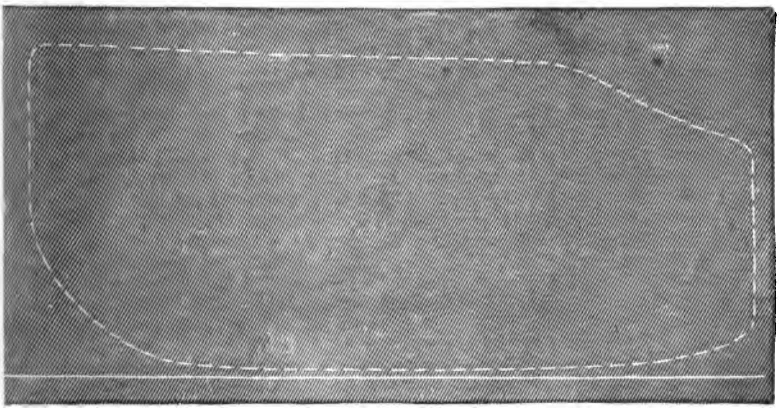


Fig. 14, scale 60 lbs., is a card from a 20x24 throttling engine, fitted with a plain slide valve cutting off at $\frac{7}{8}$ stroke; it may be considered a very good average card from an ordinary engine of this class. We introduce it here to show the improvement which may be effected when the valves and ports are given proper proportions. The boiler pressure used when this diagram was taken was 104 lbs., which is exceptionally high for this class of engine. The best initial pressure that could be obtained was 71 lbs., rep-

Fig. 15.



resenting a loss of 30 per cent., and the best mean effective pressure was 56 lbs., yielding 273 horse power. We then made a change in the valves and ports, put on a better governor and produced a card such as Fig. 15; here the boiler pressure is 93 lbs., initial pressure 78 lbs., showing a loss by throttling of only 16 per cent. The engine was made to cut-off at ⅓ stroke, which gives a mean effective pressure of 67.4 lbs., and a horse power of 318.5 horse power. This gives an idea of the great benefit which such judicious changes will secure with an ordinary engine; much better results than this may be expected from our Class E plain slide valve engines, which have been carefully designed throughout and correct proportions adopted for distributing the steam.—[Cummer Engine Co.'s Catalogue.

NOTE.—[By the kind permission of Thomas Pray, jr., editor of the Manufacturers' Gazette, several diagrams are given with very full descriptions. It is needless to say that they are very suggestive, and are shown here for the purpose of contrast with some of those previously given. The striking difference between an engine doing its duty well and economically, and those scarcely doing it at all, and at a tremendous cost, cannot fail to be observed, the first cut is an exception to those that follow.

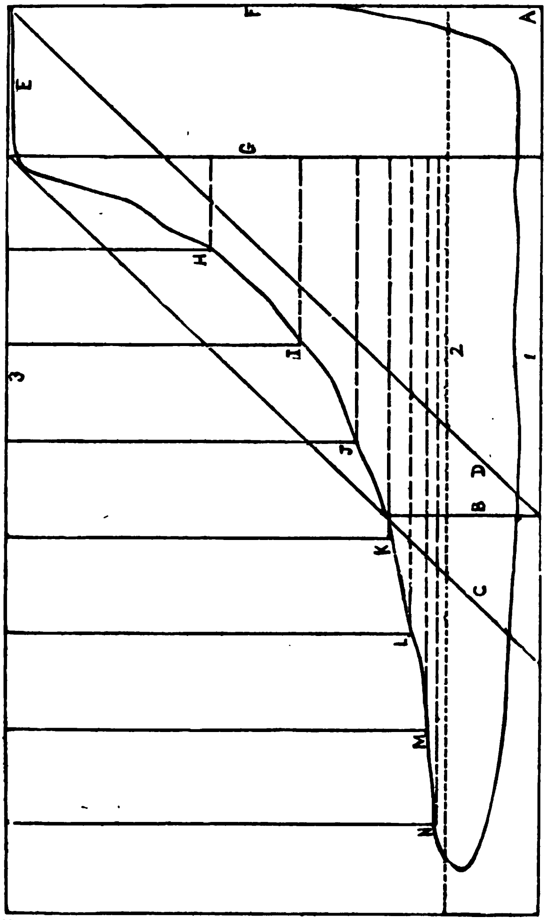
Our diagram this time is from the Buckeye engine, 24 inches diameter, 36 inches stroke, 100 revolutions, condensing, one of a pair, front end of the left hand. Boiler pressure 72, scale 30, new Thompson indicator, and was selected from three sets sent us by the engineer in charge, who took the diagrams himself.

We have made this a little fuller in the demonstration than usual, for as our list of readers is rapidly extending, many new ones have not yet become acquainted with our method of laying out the curve. We have made this so that they can get from it the information they desire and be working all towards the same point. In this case 1 represents the absolute vacuum, 2 the atmospheric line of the instrument, 3 the line of realized pressure in the cylinder, which is 68 lbs. plus, or a little less than 4 lbs. below that of boiler pressure at the instant of taking. B is our best line from which the whole demonstration is done with reference to the point of cut-off; B is drawn from a point a little to the left of the centre of the line of expansion, from that to the base line of absolute vacuum. From the intersection of the lines B, 1, the line D is drawn to the intersection of 3, F, representing respectively the realized pressure in the cylinder, the line 3, and F, the admission line. In this case we do not know what the clearance is, so we have guessed at nothing, but have assumed that the indicator made exactly the lines showing the work done, so that no clearance is included. We show the steam used, and as we do not know what the clearance is, we prefer to call it an unknown quantity, and not guess at its being two per cent. or anything else.

C is drawn parallel to D exactly, starting from 1 and intersecting exactly the line B, at its intersection of the expansion line. Wherever this line strikes on 3, that is the mechanical point of cut-off, assuming only that geometry is correct in its application; wherever the intersection of C, 3, comes, there is the point of cut-off, which in this case is perceptibly a trifle longer by the instrument than by the demonstration. Now we do not believe in the system of ordinates or logarithms where pressure and temperature are combined, but we believe if a mechanical demonstration is capable in any one direction, that a mechanical demonstration is good enough for us to locate our point of cut-off, and not be guessing, supposing, assuming, etc.; hence we make the whole of our demonstration mechanically rather than by assumption.

We could very easily erect a supposed theoretical line and it might be one of the several "isos," but our plan has always been to get at something tangible, and, instead of the isothermal or adiabatic, or isodynamic or iso-

diabolic, we have been trying to get at the iso-coal-pile line, not exactly the "always-coal-pile," but the least coal pile, so that we base our assumption on the fact that it requires 16 ounces to the pound and 33,000 pounds per horse power, and we do not assume either one way or the other, but demonstrate, therefore, that the intersection G, our first ordinate with the line 3, is the actual point of cut-off from that part of the expansion line where we have located the line B. Now from the point A all these lines radiate. From the intersection H 3, I 3, J 3, etc., whereever these lines cross G, the first ordinate, from that point at right angles draw a line to intersect with each one of the ordinates, with a line from the top of the same ordinate which crosses the ordinate G; note, therefore, the dotted line H, and a line at right angles which crosses from H to G, and notice also that where this line at right angles to the ordinate H leaves H, it is precisely at the crossing of the corresponding line of the diagram.



This applies to the other ordinates; where the broken lines are drawn, notice that it is barely above the angle formed by the two lines at I, almost exactly at J, slightly differing at K, L, M, and just perceptible above N. The points where the lines intersect at right angles to each other are the points where the lines should have gone if steam should expand absolutely according to the laws which are supposed to govern it, and which under certain conditions form a hyperbola or hyperbolic curve. We locate the point of cut-off mechanically, and then demonstrate the theoretical curve mechanically, so that we notice here a variation of far less than the width of the line, and while this may not be within one ten-millionth, it is yet so near that it shows us clearly that the valves of this engine must have been working

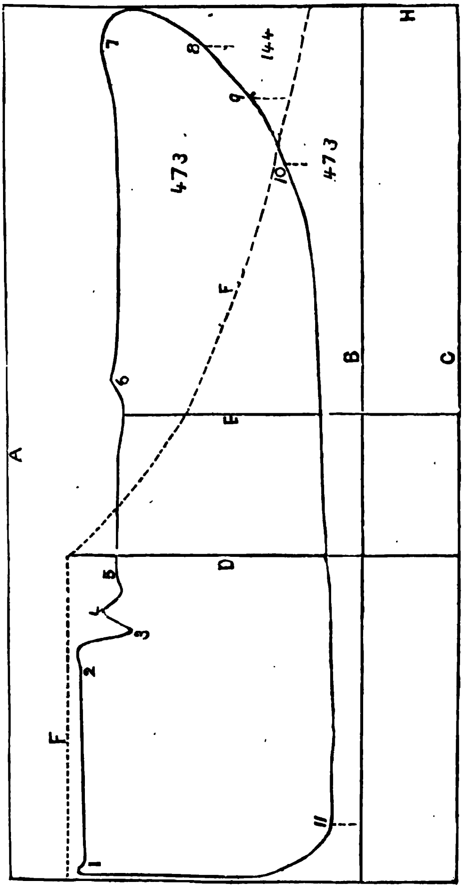
very nearly tight. Practically they are tight, and wherever any broad variation from the actual line of the theoretical curve from the point of cut-off with this demonstration occurs, you may commence at once to look for leaky valves, piston rings or something of that sort, and it does not make any difference what it in this case means, for really it means nothing; we are without the clearance line, and this diagram as it stands is simply and purely an actual exponent of the work being done at the time, but it does not show the whole bulk of the steam used, only as we know precisely what the clearance of that end of the engine was, but for all practical purposes we would not give a farthing to know. We have a diagram here which shows a very fine working of steam so far as taking, carrying, cut-off, expansion and release go. The vacuum might, perhaps, be improved in amount. It starts with only 4 lbs., runs down to 9, 10, 11, then commences to go the other way, making a fine compression though possibly a trifling steam lead.

One point must be taken care of in locating this basis for the demonstration, and that is that the ordinate B should never be drawn too early in the expansion line, for steam is like any other body where work is being done, as a steamship or a train of cars, it takes a little time for the engine to get to pulling, and so it takes a little time for the steam to settle down to its expansive work, and that place which is fair for it, all things considered, is a trifle beyond the centre or when the speed of the piston is very slightly diminished by getting up on the crank; in other words, where the speed of the piston is very slightly slower and the pressure of steam has very considerably diminished.

An example like this from the every-day work of the mill, is worth a bushel of incipient engineers' tests, or learners who expect to rival the great engineers of the day, if they live long enough. This diagram does not come from a nondescript, but from a practical working-man, who knows very well how to handle the indicator and is saving handsomely for his employers.

In the following card we have something not only to think of, but something which we can compare as between the application of geometry to fact and geometrical delineation, by so simple a process that every one of our readers who has a planimeter can, in fifteen minutes, tell whether we are correct or not. We have chosen about as awkward a diagram as we could conveniently. A represents the line of boiler pressure, it is a good way above the realized pressure; B represents the atmospheric line of the instrument; C represents absolute vacuum from which all computations are made both for geometrical demonstration of the point of cut-off, and quite another demonstration having nothing to do with the first, which gives us the theoretical curve, supposing steam does expand according to Mariotte's law and Rankine formulas are made, but the two demonstrations are not in anyway connected, beyond that the line D shows the amount of steam used in the cylinder, and the intersection of line D with the line F, shows point of cut-off on the line F. The engine from which this was taken was running 82 revolutions per minute, scale 30, governed by one of the throttle governors and was supposed to be doing good work. The card made by the indicator starts off with 45 lbs. initial pressure, makes a nice little jog at 1, runs along at 45 lbs., and commences a peculiar gyration at 2, dropping off suddenly from this point to 3, rising again to 4, and making a peculiar short curve, commencing at 5 again to run in a straight line, and at 6 another peculiar vibration. The terminal pressure at 7 is 41 lbs. We have thus a very peculiar expansion line, and almost anyone with any knowledge of steam enginery would pronounce it not by any means a model card, but we have less to do with this than with the next factor in this most interesting case. A little beyond 7 the exhaust valve seems to

commence to open and opens very slowly, so that at 8 we have 24 lbs. back pressure, at 9 we have 17 lbs., and at 10, 10 lbs. The back pressure gradually becomes less until the exhaust valve closes at 11; where it has reduced itself to 5 lbs., here we have all the space bounded between the exhaust line of the instrument and the atmospheric line of the instrument, D making a large area, the exhaust being, perhaps, a little less ragged than the upper line 1 to 7. The closing of the exhaust valve at 11 is very nearly correct, but the opening from and after 7 shows distinctly that the motion of the valve is incorrect, in its proportion to the stroke, and all the area when open is not sufficient, hence we do not realize the theoretical line of exhaust. The planimeter reading of the indicator card precisely as it comes from the instrument is 473; the planimeter reading of the area covered in by the back pressure is 144; then we have an area of 473+144=617, Now there are parties in the world who claim (we will not call this horse powers) that in this case the 473-horse power is transmitted to the machinery, and that the 144 amounts to nothing. Perhaps this is so. All engineers know that the boiler capacity is invariably measured from the atmospheric line, and in this case the boiler would receive credit for, and would actually be doing 617-horse power. It is claimed also that the back pressure upon one end equalizes the back pressure on the other; perhaps this is so; possibly not. Now, while the piston moves from 1 to 7, the steam is escaping from the other side of the piston, and from 7 to 11 is going on, the other side of the piston. Now if we have 473 on one side of the piston, 144 added to it, if it were working as it should, but in this case, working against it,



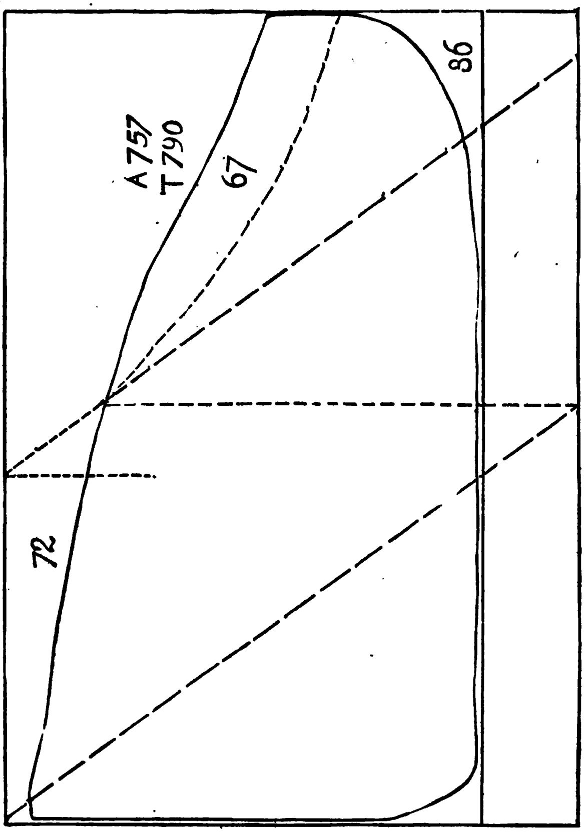
does it require anything on the other side of the piston to push that 144 out of one side of the piston and out of one end of the cylinder, while the steam is making the card upon the side of the piston in the direction of from 1 to 7? Now if this statement is a fallacy, will somebody show us where? In other words, we have drawn the line E from the expansion line or steam line, whatever it may be, to the line C; from the base of E we

have drawn a line to the intersection of F G, namely, realized pressure, and the boundary line of the card, giving the steam and vacuum lines, parallels to this line, which is omitted in the engraving. We have drawn from a point on C to the line F, which cresses the line F at the intersection of D F, from this point we drop the line D. Now the space bounded by the line C G F D, represents the volume of the cylinder at which steam should have been cut off, in order to produce its equivalent at E. Then by the same plan given in "Twenty Years with the Indicator," we draw in a theoretical line F. Now we assume here simply that had the steam horse been handled as an engine should have been, it had a pound or so above the actual initial pressure, it would have been cut off at D on the line F, and then if the valves were tight, it would have expanded according to the curve F, and if it had exhausted it, as it should have done, it would have returned upon the line B. Now there is something curious about all this. The dotted steam and expansion line with the correct exhaust gives us precisely the same planimeter reading as in the diagram above, 473 without the 144 back pressure. This may be the correct way of working engines, we mean the actual diagram, but in our own demonstration we have only shown what the engine should have done. providing the steam was worked correctly and at the real boiler pressure, instead of that which was used. It is a little curious that this result comes out precisely as it does, without any calculation other than that all the simple demonstration and the addition of about one-third of an inch in length for clearance. It is probably economical to run this engine with thirty per cent. back pressure, as a young gentleman, who has lately assumed to know something of steam, recently finds it profitable to heat some rooms by back pressure on a small Armington & Sims engine, running about 300 revolutions per minute. The back pressure somehow didn't work; direct steam was used and it took a heap less coal. This card is something for the boys to think over, and we are sure that our readers will give it careful attention, and if so they will find some curious results in the figures. The theoretical diagram laid out from the boiler pressure for cut-off, and from the initial pressure for expansion, gives absolutely the same. Our card made on the instrument, with more than forty per cent. less fuel, figures both on the same evaporative efficiency. Curious, isn't it? Where then is the fallacy, in fact, or in fancy? It may interest many of our readers to follow this carefully out.

NOTE.—These cuts are introduced with the most of the explanation and description as given by Mr. Pray. They convey a great deal of pointed information, which is irresistible. But at the same time the Author of this work does not fully concur in what he has stated, or endorse all of his views.

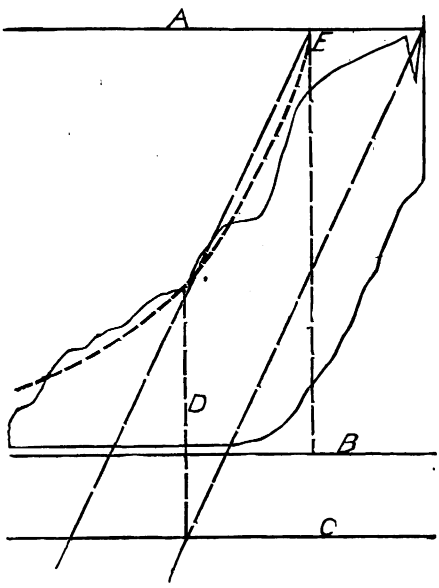
The following diagram this time is one which is interesting, and at the same time only requires a brief glance from the experienced engineer to show him that the best thing to be done with the engine is to make scrap of it, if fuel is of any account or regulating is desirable. The diagram in question was taken from an engine twenty years of age, fitted with poppet valves and a combination of what was known as the Sickle cut-off. In other words, the cut-oft is fixed, and the steam follows the same length of stroke under all conditions, when once it is fixed. This is possibly one of the engines built years hence to avoid Mr. Corliss's patents. The data is 14 inches diameter, 36 inch stroke, 58 revolutions, boiler pressure 75, scale 30. While the valves of the engine evidently have a very large capacity, they have not enough to fulfil the conditions of a perfect working engine by any means. The admission line is very good, 70 lbs. are admitted into the cylinder as initial, while only 62 lbs. are found at the demonstrated point of cut-oft. From the demonstrated point of cut-off to the visible point further down on the line, the pressure falls off to 48 lbs., and it is a

self-evident fact to us that the valves of the engine are leaking, or that by some means steam escapes into the cylinder after the valves should have closed. For the sake of illustration we have drawn in our own demonstration of the actual point of cut-off from the pressure about the centre of the stroke. The theoretical curve is drawn from boiler pressure and shows what would be accomplished if the engine was using the steam to the best advantage. The exhaust will be seen to be materially clogged, showing that whatever amount of steam is admitted it is very hard work to allow



the steam to get away. The amount and effectiveness is a questionable quantity if exactness is sought, but there is, however, some comparison that can readily be made as, for instance, the actual line of the diameter by the planimeter measures 757. Now, if we take the theoretical or demonstrated line, if the engine had been capable of admitting boiler pressure, cutting it off and treating it properly, exhausting freely and then following the boiler pressure, the theoretical line, and complete exhaust, we should have 790. Hence, if we say the actual is 757, the theoretical is then

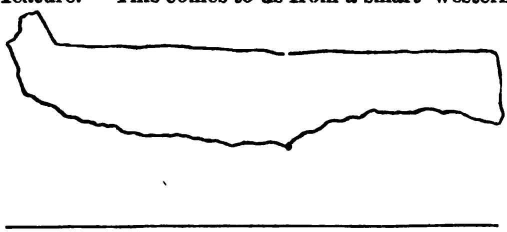
790. But there is a vast difference as between the actual and the actual minus the outs. We have a back pressure here, which amounts to 30. For economy, therefore, we shall need to say, the actual 757, minus 30, equals 727, minus 67, equals 660, the 67 really being steam sifted in, in an attenuated form, lacking in economy and completeness, and we have also another factor, minus 72, effective steam not introduced into the cylinder. Of course this would not all figure for horse power, but it will figure for units of heat from the boiler, converted into indicated horse power in efficiency, or in other words, it costs much more to maintain the horse power with steam which has been attenuated or weakened, partly turned back to water again, than it does where it comes plump and flush through the ports and passages, and then goes away plumply again. But this engine is decidedly overloaded as well, and without entering into all the particulars, the engineer asks what we suppose the parties have lost in running it. We should say, without any scruples of overstating the case, they have lost over one-half of their fuel, and, without any doubt have had irregular speed for the greater portion of the twenty years, and this in cotton machinery is quite as essential as the cost of fuel, for without the nearest approximation to perfect speed, we get a reduced production, and a reduced production in every case means increased cost, so that the question is just as broad as it is long, and the only elements entering into it are not at all the lines on the indicator card. The card is capable of easy demonstration and the most expensive luxury in steam engineering. Practically it is a poor and expensive card, theoretically it is much more so.



The diagram in this case is from a Ball engine 9x12 inches, running 200 revolutions, steam pressure at the moment 65, scale 30, old Thompson indicator. The steam pressure here is taken after a little vibration of the instrument. The steam line starts off at 65 lbs., falls off nearly 8 lbs. at the point of cut-off; the expansion line is somewhat irregular as in all high pressure engines. The release is at 14 lbs. above the atmospheric line and gives a very good opening indeed. The exhaust in this case is about 1 lb., and is very regular until the closing of the valve and commencement of compression. A is boiler pressure and is drawn about two pounds above in order not to distort either line of the diagram. D is the base line raised from the vacuum line C. From the intersection of the line C D, the parallels right and left are erected, giving us the point of cut-off at E on the line A. The theoretical line follows the actual line of the instrument very closely indeed, running a little above and a little below. It would interest some of our readers to use the planimeter on this and see that the sum is almost precisely an

equivalent one to the other. The theoretical curve F drawn from the point E due to the pressure D, according to formula, shows a very good working of the steam; a possibility exists in our own mind that the engine may be somewhat throttled, perhaps in the valve or pipe, for we have seen better steam lines from the same make of engine. This engine has been running some months. The diagram is one of several, not taken as any having especial merit, but from the actual work of the machine. B is the line of rest of the indicator, C vacuum line; the dotted lines are our own, the other lines are precisely as left by the instrument. As a specimen of every-day work it is very good. Clearance not known, or it would be interesting to work out the water consumption per horse power from temperature and volume.

The diagram with this card comes with the following note: "At first sight you will probably conclude that it was taken from a low-pressure cylinder of the engine on Noah's Ark, but it was not. It is from an elevator engine which throttles its steam on the exhaust side. The elevator had about one-half ton of goods at the time. The diagram is correct in every feature." This comes to us from a smart western town, and if this "diagram is correct in every feature" then eastern steam boilers have a heap to learn.

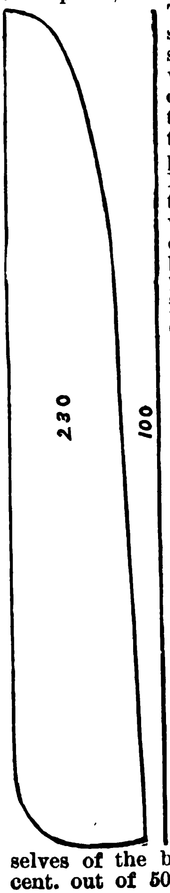


The dimensions are as follows: Cylinder diameter 8 inches, stroke 10 inches, clearance ½ inch, scale 40. 200 revolutions per minute, boiler pressure 50 lbs. The steam is admtitted very peculiarly. The distance it is carried is exceedingly short, the pressure falls off very quickly and then seems to follow an alm ost sraight line the whole length of the stroke. The commencement of the exhaust is rapid, almost like locomotive work in some respects, and then comes throttling. whether for regulation or otherwise we do not understand. The piston commences its return stroke under 19 lbs. back pressure; this is increased to 23 lbs., falls off to 16 and then runs up again to 27 lbs.

The compression commences somewhere between half stroke and the end of the stroke, or the compression may perhaps be changed in the back pressure. This action of steam is very peculiar, to say the least, is not by any means economical and what kind of regulating they must have by throttles of steam on the exhaust side is a question. Perhaps our correspondent was a little sarcastic in this. We should judge that something throttled the steam materially. as the engine starts with about 45 lbs. on the piston. carrying 35 lbs. the whole length of the stroke. It only shows, perhaps, the vagaries of somebody's idea of working steam.

The diagram on the following page was taken from a so-called high-speed engine, running 120 revolutions a minute, with a boiler pressure of 90 lbs. Steam is rather late in getting into the cylinder; only 45 to 46 lbs. are realized on the piston, and this is carried almost in a straight line the whole length of the stroke. The exhaust is badly deficient in our eyes; but the advocates of the back-pressure theory must rejoice at such an instance of their favorite doctrine in which back-pressure costs nothing, requires nothing, amounts to nothing, except "a fallacy in the minds of reasoning men." But facts are facts, and steam users begin to find that bantling engineers are an expensive luxury. It does not matter whether

they are the graduates of a newspaper office, a technical school or any other place, so long as they lack that one essential, practical experience.



This engine to which we refer, was pronounced "reasonably economical for its class" by one of these assumed experts. It was afterwards carefully indicated with the result shown, 60 spring; the area of the indicator card proper, without back pressure, is 230 on the planimeter, the back pressure is 100, so that we have 33 parts of the whole load, 23 of which are effective and ten are back pressure. The actual indicated load of the engine was 17.3 horse power, the boiler was called on to do 25 or 26; the amount of fuel used was 3100 lbs. in ten hours, and if we figure this according to the bantling theory, we have only 19 lbs. of fuel per horse power per hour, as indicated by the engine; while if we take the actual duty of the boiler, which gives us 25 horse power actually performed in effective work and back pressure, it then reduces the coal consumption to 12.4 lbs. per horse power per hour. Working near by this was an engine owned by the same party, which was carefully indicated, and the result was so considerably against the back pressure fallacy and the theoretically-educated young man and his report, that the owner went into the market and bought a Harris-Corliss second-hand of double the capacity, wishing to run two buildings. After the changes were made his second-hand engine was indicated from the same boilers and steam-pipe connections, except the valve, that the old high-speed, theoretical-expert engine was run from. His engineer, on indicating this engine several times a day for two weeks, made the average load 64-horse power. The actual amount of fuel burned during the two weeks, averaged 3100 pounds per day, doing 64-horse power, ten hours, reducing the fuel from the old arrangement of nineteen pounds per hour to less than five, and with a second-hand Harris-Corliss which had not seen service for several years. Now the question is, if fifty per cent. back pressure costs nothing, how much does a hundred per cent. cost? Or, like some of our late dissertations on indicator practice, if the whole load requires 52-horse power and you then add 122 of back pressure, and still do the whole load on 44, where does the economy come in, in ridding themselves of the back pressure and reducing the amount of fuel 400 per cent. out of 500?

WATER CONSUMPTION.

By permission, the following diagrams and explanations were taken from Buckeye Engine Co.'s catalogue:—

Having found the M. E. P., as previously explained, we next want the terminal pressure, which is found by extending the expansion curve to end of the diagram, and measuring from that point to vacuum line by the scale of the diagram. (See T V. Fig. 16.)

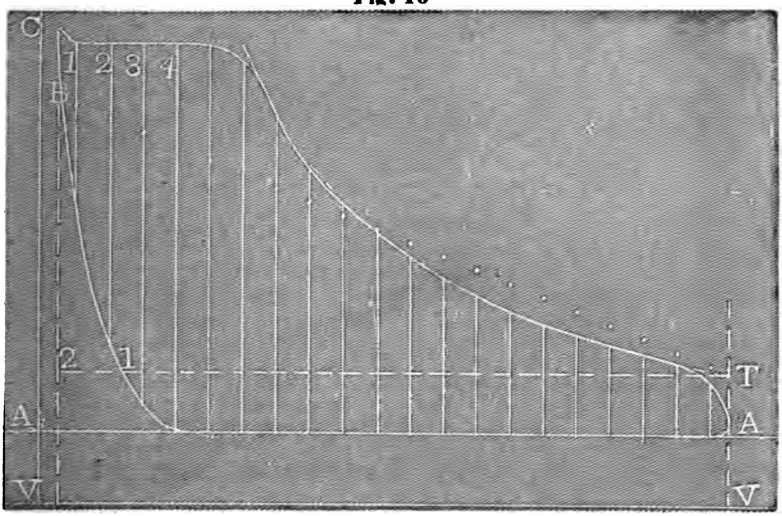
The economy of a steam engine.—This is expressed in terms of the number of pounds of water consumed per H. P. per hour. The rate of

water consumption is the only intelligible expression for the engine alone, as the amount of fuel used must depend largely upon the kind of boiler and its condition, the manner in which it is set and fired, the quality of the fuel, the draft, and numerous other conditions, for which the engine is in no way responsible.

This rate may be found by the following rule: Divide the constant number 859.375 by the volume of steam at the terminal pressure, and by the mean effective pressure. The quotient will be the desired rate.

This constant is the number of pounds of water that would be used in one hour by an engine developing one H. P. if run by water (instead of steam) at one pound pressure per square inch. Then, with pressure of more than one pound the amount required would be as many times less as the pressure was greater than one pound, and when steam is used, the amount would be as much less as the volume of the steam at the pressure at which it is released is greater than that of an equal weight of water. Hence the above rule. The constant is found as follows: The standard H. P. being 33,000 foot-pounds, or 33,000 lbs. lifted one foot per minute, would be equivalent to 33,000×12=396,000 lbs. lifted one inch per minute. Hence an engine whose piston displacement was 396,000 cubic inches per minute, would develop one H. P. with one pound M. E. P. on the piston. This for one hour would be 396,000×60 minutes=23,760,000 cubic inches per hour. Then suppose the engine to be run by water at one pound pressure per square inch, instead of steam, and taking the number of cubic inches of water per lb. at 27.648, 23,760,000÷27,648=859,375, which is the desired constant.

Fig. 16



EXAMPLE:—Diagram Fig. 16 was taken from our 12x20 inch automatic engines, speeded 140 revolutions per minute. Scale of diagram, 40 lbs. per inch. Applying the rule of analysis, we find first that the combined length of the 20 lines, 1, 2, 3, 4, etc., is $21\frac{1}{10}$ inches, showing that we have $42\frac{2}{10}$ lbs. M. E. P.

The terminal pressure (T. V.) is 27 lbs.; the volume at that pressure is given at 926; that is, one cubic inch of water at a temperature of 60°, makes

926 cubic inches of steam at 27 lbs. pressure per square inch. Hence by the rule the rate of water consumption becomes $\frac{859875}{926 \times 42.7}=21.74$ lbs. of water per I. H. P. per hour.

But early exhaust closure saves some steam, while exhausting from the clearance at a pressure greater than the back pressure wastes some, and the process, so far, makes no allowance for either. When the maximum compression equals the terminal, the loss and gain are equal, but when the compression exceeds the terminal, there is a balance of gain from compression equal to the excess of steam compressed into the clearance space over that exhausted from it, and when the terminal exceeds the compression, there is a balance of loss due to exhausting from the clearance space, hence the following rules:—

To make allowance for compression and clearance. 1st. Fix the terminal pressure at point T (Fig. 16 and other diagrams), where it would have been if the steam had not been released till the end of the stroke was reached.

2d. Draw the line T 2 parallel with the atmospheric line, which will cut the compression line at 1, at which point the quantity of steam exhausted from the clearance has been restored, and the consumption will be as much less than the rule shows, as the line T 1 is shorter than the line T 2, or the length of the diagram.

3d. Multiply the result obtained by the rule by the length of the line T 1, and divide the product by the length of the line T 2. The result will be the rate of consumption corrected for both clearance and compression.

EXAMPLE.—The result obtained from the rule is 21.74 lbs., the length of line T 1 is 3.17 inches, and the length of line T 2 is 3½ inches, hence $21.74 \times 3.17 \div 3.5 = 19.69$ lbs. per I. H. P. per hour, the corrected rate. It should be understood that this rate is theoretical, and assumes perfect conditions, such as dry steam, entire absence of loss from leakage, condensation, etc.

Fig. 17.

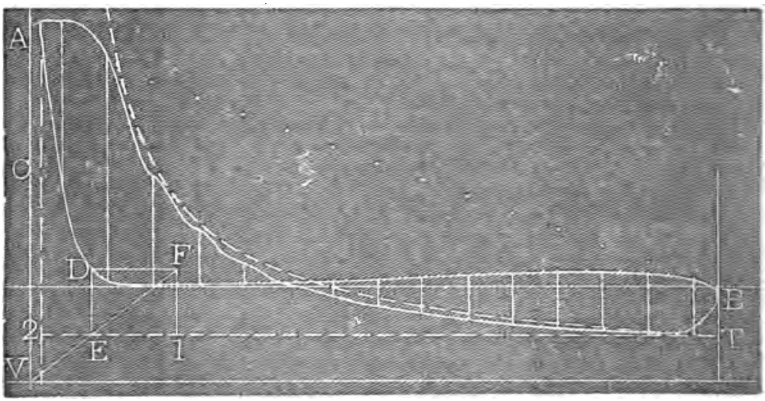


Fig. 17 illustrates our method of finding the point 1 (T 1) in the terminal line, when the line is located below the atmospheric line, and conse-

quently below any part of the compression curve defined on the diagram.

Select any point in the actual curve, as at D. From that point draw a line at right angles to atmospheric line, to terminal line, as at E. Then from V, where the clearance line cuts the vacuum line, draw a diagonal line through point E to point F (same height as point D), then a line at right angles to atmospheric line from F will cut the terminal line at the proper place for point 1. The process will be recognized the same in principle as that used for finding a point in the isothermal expansion curve.

The consumption for Fig. 17 is as follows:—

The M. E. P. is 2 lbs., and the T. P. is $6\frac{3}{4}$ lbs. The volume for $6\frac{3}{4}$ lbs. is given as 34.27 (the mean for $6\frac{1}{2}$ and 7lbs.), hence $\frac{8595}{34.27\times2}$=125.4 lbs. Line T 1 is $2\frac{3}{4}$ inches long. and line T 2 (or whole length of card) is $3\frac{1}{2}$ inches, hence $125.4\times2.75\div3.5=98.53$ lbs. per I. H. P. per hour, the correct rate. This will serve to show the utter absurdity of very light loads.

Fig. 18.

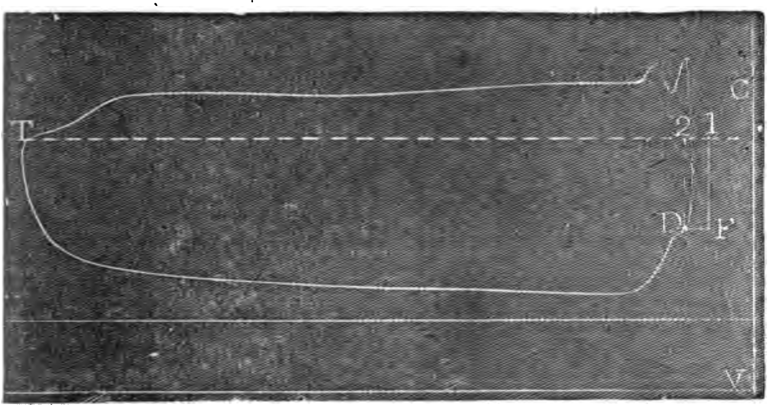
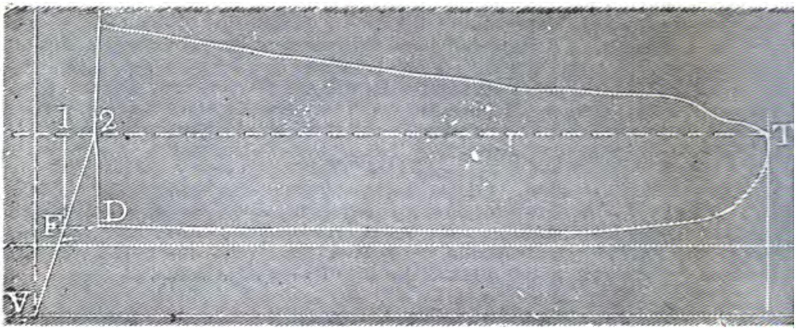


Fig. 18 illustrates a method of locating the clearance line from the conformation of compression curve, as follows: First select two points in the curve and form a parallelogram through said points as illustrated. Then draw a diagonal line through points F 2, till it intersects the vacuum line, the clearance line will be a vertical one drawn from said point of intersection, as at V. The degree of accuracy will depend upon the perfection or tightness of piston and valve, leakage generally having the effect of showing too much clearance.

In diagrams like Fig. 19, wherein no compression is present, the proper place for point 1 on the terminal pressure line can be found as follows: First, locate a clearance line in accordance with the best data at hand, draw a diagonal line from the intersection of terminal pressure line with the end of diagram, to intersection of clearance line with vacuum line (see 2 V). the diagonal line will cross a continuation of the back pressure line immediately under the proper place for point 1 on terminal line. In this case the result obtained from the rule will be increased, because the multiplier (distance T 1) is the larger number in the correction. A knowledge of existing clearance is necessary, as such diagrams furnish no clue to it. But the expansion curve of a cut-off diagram does furnish a clue to the volume of clearance, unless the curve is vicious in its formation.

Fig. 19.



The computation table on page 41 furnishes a very short and accurate method of finding the rate of water consumption due to indicator diagrams. The mean effective pressure being the measure of *the power developed*, and the total terminal pressure (T. T. P.) the corresponding measure of the consumption or *cost of the power*, it follows that we should find a number, which, if multiplied by the T. T. P. and divided by the M. E. P., will give the rate of water consumption at once, excepting, in many cases, a required correction for compression and clearance.

Thus far the constant number 859,375 in connection with the volumes of steam, has been used for computing the rate of water consumption. To make the process available, a table of volumes must always be present, and to render our instructions complete we should publish such a table, but in lieu of that, we submit on page 41 a computation table as above stated.

EXPLANATION.—The numbers in P columns are so many T. T. P.'s and the numbers in column W are the numbers sought, as previously referred to above. Each of the numbers under W will therefore represent the rate of water consumption, for a diagram having both M. E. P and T. T. P. the same as the number to the left of it under P, and when any given diagram has a M. E. P. greater than its T. T. P. its rate of consumption will be proportionately less than if they were the same, and if the M. E. P. is less, the rate will be proportionately higher.

Hence the rule. Find in column P the total terminal pressure of the diagram or the number nearest it. (For fractions of a pound in the terminal, an approximate average of or mean of two numbers should be found, to insure accurate results.) Then multiply the number under W opposite the number so found by the T. T. P. of the diagram, and divide the product by its mean effective pressure the quotient will be the rate in pounds of water per I. H. P. per hour, subject, however, to the corrections for compression and clearance, as previously explained.

EXAMPLE FOR USE OF TABLE.—Referring to Figs. 16 and 17. First, Fig. 16, its terminal pressure is 27 lbs., M. E. P. 42.2, number under W for 27 lbs. is 34.37: T 1, 3.17 inches, and T 2, 3.5 inches. Then $34.37 \times 27 \div 42.2 = 21.99$ lbs. water. Correction, $21.99 \times 3.17 \div 3.5 = 19.91$ lbs. water per I. H. P. per hour, rate correction. For Fig. 17, terminal pressure is 6.75 lbs., and its M. E. P. is 2 lbs.; the number under W for $6\frac{3}{4}$ lbs. is 37.3 (got by adding to the number for 7 lbs., $\frac{1}{4}$ the difference between numbers for 6 and 7 lbs.) The distance T 1 is $2\frac{3}{4}$ inches, and the distance T 2 is $3\frac{1}{2}$ inches. Then $37.3 \times 6.75 \div 2 = 125.89$ lbs. water. Corrected for clearance and com-

pression, $125.89 \times 2.75 \div 3.5 = 98.91$ lbs. water per I. H. P. per hour, the theoretical rate properly corrected.

The reader may notice that the result obtained by the use of the rule does not agree exactly with that obtained by the use of the constant number and the volumes. This arises from the fact that the tables of volumes published are not exact, but are the nearest approximation without using decimals. On preparing our table and carrying out the numbers to two decimal places, these inaccuracies produced very noticeable irregularities, and in order to correct them we selected several points along in the volume tables that proved most nearly correct, and then reduced the intermediate points to a curve cutting these points. The result is, our table will be found more accurate and reliable than any of the tables of volumes published. The process is independent of any knowledge of the size and speed of the engine,—a diagram and its scale being all the data that is required.

PRACTICAL HINTS ON MANAGEMENT.

To a competent engineer, the following advice would be deemed unnecessary, as all have their own methods of arriving at the same results. In the care of bearings, keying up and tightening, attention to oiling, avoiding unnecessary heating, packing, keeping joints tight, and other minor matters, are only thoroughly acquired by care, watchfulness and good judgment. One having these necessary qualifications and a desire to become a successful engineer will *succeed.* If he is a good mechanic and practical machinist in building steam engines, so much the better. If he has not any of these qualifications, he had better get into some other business as soon as *possible* and make room for those who have.

In keying up a connection, a very good plan is to drive the key hard with a soft metal hammer, and if you have not a permanent mark make a temporary one with your greasy thumb across the gib and key next to the strap. Drive the key back as much as is necessary to prevent heating. If the crank, pin, or any part is out of line, it will require to be looser than otherwise. If you are in doubt where the pound is, put on a little oil (when the engine is working); the pound will stop for the instant, if you have found the right place.

The best cure for heated bearings is, not to let them *heat*, but with the best engineers this will happen sometimes. A good remedy for large bearings is fine plumbago and sperm oil if it can be obtained, otherwise castor or good lubricating oil, or take off the top box (when there is not a large hole in it), and while the shaft is slowly turning put on white lead ground in oil from the keg. When the lead is seen coating the bearings as it turns slowly, it shows that the lead has interposed itself between the two surfaces and will cool down, when the ordinary lubricant may be resumed.

Avoid using water if possible, but do not endanger melting out boxes and cutting bearings, by *not* using it. Much judgment is required about these things. Many a fine engine has been ruined by want of attention, at the proper time, to these important matters.

STEAM PUMPS.

A proper management of pumps is very important. With a steam pump a very slight thing often will prevent the pump from working, per-

haps a little chip or dirt under the valves. or stoppage of the small steam holes or ports. Have a suitable strainer in the water supply pipe at some accessible point.

So much depends on the pump for water to supply the boilers, that a good deal of close attention is required in this direction. Be sure that the feed valve to the boiler is open before starting the pump. Where Injectors or Inspirators are used, you cannot use the supply water so hot, or graduate your feed as well as with a steam pump.

We insert directions from Deane Pump Co., in relation to steam pumps.

In ordering a pump, it is important to the buyer's interest that he should inform the party of whom he purchases on the following points:—

1. For what purpose is it to be used?
2. What is the liquid, or semi-liquid, to be pumped, if not water?
3. If water, is it hot or cold, salt or fresh, clear or gritty?
4. What is the maximum quantity required to be pumped per hour?
5. To what height is it to be lifted by suction, and to what height forced?
6. What is the whole length of suction pipe, and what of discharge pipe?
7. What is the ordinary pressure of the steam used?

In ordering parts for, or in otherwise referring to, a pump in use, not merely the number designating the size should be given, but also the factory number.

Directions for Setting Up and Operating Pumps.

In setting up a pump, the first requisite is to provide a full and steady supply of water (or other fluid). To accomplish this, observe the following points:—

The suction pipe must in no case be smaller than the size given in the table; if long, it must be larger, as the friction due to unusual length will partly overcome the head due to the vacuum, and prevent a full supply.

It must be as straight and free as possible, for turns and valves obstruct the water far more than length of pipe.

It must be air tight, as a very small leak will supply the pump with air to its full capacity, so that little or no water will be obtained, according to the size of the leak.

Foreign substances—such as sticks and rubbish—must not be allowed to enter the suction pipe. If there is danger of it, a strainer must be used. The aggregate area of strainer holes—on account of the added friction—must be from two to five times the area of the pipe, according to the speed at which the pump is to be run.

A foot valve must be used on long or high suctions. If one is used, see that it has as large an area as the pipe. The smallest point in the pipe is practically the size of the whole.

A suction air chamber, on the suction pipe near the pump, is always an advantage on long or high suctions, or when high speed is desired it is a necessity. It prevents pounding when the pump reverses.

Hot water cannot be raised to any considerable height by suction. If the supply is very hot, it must be placed high enough so that the water will flow to the pump by gravitation.

The steam, exhaust and discharge pipes should be straight and free as possible.

To prevent freezing, when a pump is idle in cold weather, drain it by opening all cocks and plugs provided for the purpose.

Keep the steam cylinder oiled, especially just before stopping.

Keep all stuffing boxes well and evenly filled with packing, so they need not be screwed too tight.

Let the steam end alone, if the pump begins to run badly, until fully satisfied that there is no obstruction in the water cylinder, water valves or water pipes.

Don't pull the pump apart to see what is inside, as long as it does its work well.

Use a pump well and carefully, if it is expected to work well.

USEFUL INFORMATION.—Applicable to Pumps.

A gallon of water (U. S. Standard) weighs 8⅓ pounds and contains 231 cubic inches.

A cubic foot of water weighs 62½ pounds, and contains 1,728 cubic inches, or 7½ gallons.

Each nominal horse-power of boilers requires one cubic foot of water per hour.

In calculating horse power of steam boilers, consider for tubular or flue boilers 15 square feet of heating surface equivalent to one horse power.

Condensing engines require 20 to 25 gallons of water to condense the steam evaporated from one gallon of water.

To find the pressure in pounds per square inch of a column of water: multiply the height of the column in feet by .434. (Approximately, every foot elevation is called equal to one-half pound pressure per square inch.)

To find the capacity of a cylinder in gallons: Multiplying the area in inches by the length of stroke in inches will give the total number of cubic inches; divide this amount by 231 (which is the cubical contents of a gallon in inches), and the product is the capacity in gallons.

Ordinary speed to run pumps is 100 feet of piston per minute.

To find quantity of water elevated in one minute running at 100 feet of piston per minute: Square the diameter of water cylinder in inches and multiply by 4. EXAMPLE:—Capacity of a 5-inch cylinder is desired: The square of the diameter (5 inches) is 25, which, multiplied by 4, gives 100, which is gallons per minute, (approximately.)

To find the diameter of a pump cylinder to move a given quantity of water per minute (100 feet of piston being the speed), divide the number of gallons by 4, then extract the square root, and the result will be the diameter in inches.

To find the velocity in feet per minute necessary to discharge a given volume of water in a given time. multiply the number of cubic feet of water by 144 and divide the product by the area of the pipe in inches.

To find the area of a required pipe, the volume and velocity of water being given, multiply the number of cubic feet of water by 144, and divide the product by the velocity in feet per minute. The area being found, it is easy to get the diameter of pipe necessary.

The area of the steam piston multiplied by the steam pressure, gives the total amount of pressure exerted. The area of the water piston multiplied by the pressure of water per square inch gives the resistance. A margin must be made between the power and resistance, to move the pistons at the required speed; usually reckoned at about 50 per cent.

TABLE.

SHOWING GALLONS OF WATER DISCHARGED IN FIRE STREAMS THROUGH 100 FEET OF 2½-INCH RUBBER HOSE, WITH GIVEN NOZZLES (SMOOTH).

Diam. of Nozzle.	Pressure at Nozzle.	Gallons per Minute.	Horizontal Stream.	Vertical Stream.	Diam. of Nozzle.	Pressure at Nozzle.	Gallons per Minute.	Horizontal Stream.	Vertical Stream.
1	30	134	90	62	1⅛	70	259	163	125
1	40	155	109	76	1⅛	80	277	175	137
1	50	173	126	94	1⅛	90	294	186	148
1	60	189	142	108	1⅛	100	310	193	157
1	70	205	156	121	1¼	30	210	96	63
1	80	219	168	131	1¼	40	242	118	82
1	90	232	178	140	1¼	50	271	138	99
1	100	245	186	148	1¼	60	297	156	115
1⅛	30	170	93	63	1¼	70	320	172	129
1⅛	40	196	113	81	1¼	80	342	186	142
1⅛	50	219	132	97	1¼	90	363	198	154
1⅛	60	240	148	112	1¼	100	383	207	164

LOCOMOTIVE AND MARINE ENGINES.

What has been said in regard to stationary boilers and engines is true in reference to the locomotive and marine service to a considerable extent. Locomotive boilers require closer watching of the water, as the boiler is constantly in motion, and the water used is not generally so free from impurities, being obtained from a variety of sources, particularly at the West and South. Hence the boiler should be blown out more frequently, and examined with great care. The engine being on an uncertain foundation (especially if the road-bed is in a bad condition). is liable to be constantly out of line, the only dependence being the stability of the frame. But locomotive builders understand this thing and pay particular regard to it. But, nevertheless, the boxes will not run, keyed up as tight as with a stationary. Hence the engineer must give this matter close attention.

As the subject of setting of the valves has been alluded to previously in reference to the locomotive, it is not necessary to refer to it at any length here. The speed of the engine, whether it be a freight or fast express, regulates the necessary lead, and as the draft is regulated and controlled by the exhaust in most cases, proper attention should be given to the lead of the exhaust valve. The size of outlet of exhaust pipe has much to do with the draft. No special rules can be given for these matters. All must depend upon the judgment of those having it in charge.

Marine or river boat engines and boilers are subject to similar conditions as stationary except in the former boilers. Salt water is often used as a matter of necessity, but most of the large steamships of the regular lines are provided with tanks for fresh water, and have condensing apparatus so as to avoid the use of salt water, with all its attendant evils of formation of scale, etc. But where salt water is used, frequent blowing-off is necessary, both from the surface and from the bottom; use also the salinometer often. to test the saline properties of the water, particularly on long voyages. On western river boats where the water is very muddy, frequent blowing-off is imperative.

In the marine or boat engine, the only foundation is the ship or boat, and if fastened securely to it in *line* with the keel itself, that is all that can

be done. But in putting in the machinery, the utmost care should be taken to have all the parts in line with the main shaft, or line where the main shaft is to be. All the work of course has to be placed by line, as no *plumb* or *level* can be used on a vessel afloat. The management of the engine is the same as on the land, except that, as in the case of the locomotive, convenient provision is made for reversing (by means of double eccentrics and links, or otherwise), that is, running forward or backward, as the signal of the conductor or pilot may dictate by means of the wave of the hand or lantern, or the stroke of the signal gong.

STEAM HEATING.

No positive rules can be given for steam heating, as the conditions are so varied, dependent upon locality, climate and heat required. But in the vicinity of New York we can approximate very near for all general purposes. The rule of Watt was to allow 1 cubic foot of water per hour for each horse power; hence if we measure the water condensed in the heating pipes in a given time, allowing 62.5 lbs. per cubic ft. or 7.68 gallons per cubic foot, we can get very near the quantity of steam.

Steam pipes in the ordinary circulation when run around the sides of the apartment, keeping the temperature at 60°, will condense .357 lbs. of water per hour for each square foot of surface of pipe. A coil maintaining the same temperature will condense .29 lbs. (per hour, per sq. ft.) of surface. For dwellings, when the pipes in the form of coils are placed in the cellar and supplied with air from the outside, one square foot of pipe surface, or three lineal feet of 1-inch pipe to 50 cubic feet of space to be warmed, when the coil is placed in the apartment, the same amount of surface of pipe to 65 cubic feet of space; in workshops the same amount of pipe to 100 feet of space; in stores and warehouses the same quantity of pipe to 150 to 200 feet of space. Very much depends also upon the pressure of the steam. Exhaust or low pressure steam will not have heating properties of steam at 25 lbs. per sq. inch and upwards, unless the pipe surface is increased proportionally. It is generally considered good economy to use exhaust steam in manufacturing establishments where there is a plenty of it, for heating and drying, (in such cases the cost of steam for power is slight), if the back pressure does not exceed 6 or 8 lbs. per square inch. There is no serious difficulty in running it through 1-inch pipes so long as there is enough area.

ELECTRIC LIGHTS.

This subject is occupying much attention at the present time. While it is conceded by many scientists that electricity may be the great medium of light, power and heat, for light only has it as yet assumed a tangible shape, so as to meet with any degree of success. We have gone into very minute calculations from practical observations of the working of the Arc and Incandescent system (known as the Weston and Maxim plan), in comparison with gas, as has been used the past two years in one of the prominent Lowell mills. The following statistics give the result:—

The price in this statement is given as per burner, or electric lamp, per hour, in order to readily determine the cost of each for any special outfit.

Relative cost of gas and electric lights: Price of gas $1.50 per thousand feet; coal for electric light power, $5.00 per ton.

No. 1 WEAVE ROOM.

	Mills.
440 4-foot gas burners, gas consumed, each per hour	6.9
Repairs for burner	1.14
Interest on plant $2500 at 6%	3.9
Cost per burner per hour	11.94
Whole cost of 440 burners per hour	$5.25

440 24-candle power Incandescent lamps each.

Fuel per lamp per hour, being 8 lamps per horse power	.90
Repairs per lamp per hour	.81
Care of dynamos, and oil	.16
*Interest on plant $5250 at 6%	8.04
Cost per lamp per hour	9.91
Whole cost 440 lamps per hour, being 8 lamps per horse power	$4.36

Whole cost 440 gas burners per hour	$5.25
Whole cost 440 lamps per hour	4.36
Cost of gas more than electric light, equal 20%	.89

No. 1 CLOTH ROOM.

	Cents.		Cents.
46 5-foot gas burners; whole cost each per hour	1.366	whole	62.83
6 Arc lights; whole cost each per hour	3.113	"	18.67
Cost of gas more than electric lights, equal 236%			44.16

On same basis of cost in other mills.

472 4-foot gas burners, each 11.94, cost per hour	$5.63
472 16-candle incandescent lamps, cost per hr., being 12 lamps per h.p.	3.11
Cost of gas more than electric light, equal 81%	2.52

No. 2 CLOTH ROOM.

	Cents.		Cents.
38 5-foot gas burners, cost each per hour	1.366	whole	51.90
4 Arc lights, cost each per hour	3.113	"	12.45
Cost of gas more than Arc lights, equal 316%			39.45

Cost per year, gas	$6945.75
" " " electric light	4493.64
" " " of gas more than electric lights, equal 54%	2452.11

The above is based on 165 days service of 3½ hours per day.

NOTE.—In consequence of the great reduction in price of electric light machinery and supplies since the first edition of this work was published, an entire revision of the above statement was thought best.

* Steam engine and boiler plant not included. When used independent of other power, interest on cost of engine plant, and expense of engineer and fireman should be added.

TABLE

Showing the oxygen consumed, the carbonic acid produced, and the air vitiated by the combustion of certain bodies burnt so as to give the light of twelve standard sperm candles, each candle burning at the rate of 120 grains per hour:—

Burnt to give light of 12 candles, equal to 120 gr. per hour......	Cubic feet of oxygen consumed..	Cubic feet of air consumed......	Cubic feet of carbonic acid produced.........	Cubic feet of air vitiated......	Heat produced in pounds of water raised 10° F....
Cannel Gas..............	3.30	16.50	2.01	217.50	195.0
Common Gas...........	5.45	17.25	3.21	348.25	278.6
Sperm Oil.........	4.75	23.75	3.33	356.75	233.5
Bensole.................	4.45	22.30	3.54	376.30	232.6
Paraffin	6.81	34.05	4.50	484.05	361.9
Camphine	6.65	33.25	4.77	510.25	325.1
Sperm Candles...........	7.57	37.85	5 77	614.85	351.7
Wax	8.41	42.05	5.90	632.25	383.1
Stearic	8.82	44.10	6.25	669.10	374.7
Tallow....................	12.00	60.00	8.73	933.00	305.4
Electric Light............	none	none	none	none	13.8

There you see why the electric light is so pure and so healthy. There is no consumption or pollution of air. There is the smallest possible production of heat. There are none of the existing dangers from fire or suffocation but all is pure, healthy and safe.—[Electrical Review.

SHAFTING.

In putting up shafting, care should be taken to place the main line parallel and level with engine or line of water wheel. If those are not already in, they should be so placed as to be in line with the walls of the building where the main line is to run. Always place the engine if possible, in such a position so that the main belt will be at an angle of about 35° with the floor, and sufficiently distant from the main line to cause the belt to sag from 4 to 6 inches in its length, dependent upon the width of belt and power required to transmit, and have the bottom side the driving or tight side. Whatever slack there may be, will fall upon the top side of the pulleys and give additional power. Do not place the face of a driven pulley, perpendicular to that of a driver if it can be avoided. In making a quarter turn with the belt, the best plan is to use a (mule stand) which is a perpendicular shaft with two idle pulleys upon it. It should be placed not less than 10 times the width of the belt from the shaft. If the two shafts are on the same plane, or level, the idlers can also be level, but if not, they must be placed at such an angle and position as the distance from the face of the top side of the driving pulley around the centre of the upper idler to the top of the driven pulley shall be the same as the distance from the bottom side of the driven pulley around the centre of the bottom idler to the bottom side of the driver.

The mistake is often made that a belt will always run to the highest point on a pulley. This is true when the two lines of shaft are level or

parallel with each other, but if not, the belt will run to the nearest point, and the only way to prevent it is to place the driven shaft in line, or parallel with the driver, or enlarge the slack edge of the driven pulley until its face is parallel with the driver. The latter expedient is not recommended, as it would soon spoil the belt. In placing a shaft for a quarter turn where the driven shaft is 10 ft. above or below, the centre of the face of driving pulley on the driving side should be perpendicular to the driven edge of the driven pulley. These points with a good mechanic are soon learned by experience.

MISCELLANEOUS.

In the succeeding pages it is proposed to treat of the various subjects that come into the general practice of the thorough engineer and mechanic, in the course of which, illustrations, rules and tables are given to facilitate calculations in connection therewith, while much of it is new the balance is made up with careful selections from known reliable authors as best adapted to this work (for which due credit is given.) It is hoped that much valuable information may be gained from its study.

TABLE

OF SIZES OF PATENT COLD-ROLLED SHAFTING, PISTON AND PUMP RODS.

Diameter	Wei't pr ft.	Diameter.	Wei't pr ft.	Diameter.	Wei't pr ft.	Diameter.	Wei't pr ft.
4½	53.76	2⅜	14.76	1½	5.89	13-16	1.74
4	41.88	2¼	13.25	1 465-1000	5.52	¾	1.47
3¾	36.81	2 3-16	12.54	1 7-16	5.41	11-16	1.24
3½	32.07	2⅛	11.82	1⅜	4.94	⅝	1.02
3¼	27.65	2	10.47	1 5-16	4.51	9-16	.837
3	23.56	1 15-16	9.83	1¼	4.09	½	.654
2 15-16	22.65	1⅞	9.20	1 3-16	3.70	15-32	.582
2⅞	21.63	1 13-16	8.65	1⅛	3.31	7-16	.511
2¾	19.79	1¾	8.01	1 1-16	2.96	43-100	.503
2 11-16	18.80	1 11-16	7.45	1	2.61	⅜	.368
2⅝	18.03	1⅝	6.91	15-16	2.36	5-16	.258
2½	16.36	1 592-1000	6.60	29-32	2.18	¼	.165
2 7-16	15.55	1 9-16	6.40	⅞	2.00		

Each shaft made to Whitworth gauge. The shafts are kept on hand in lengths of 20 feet, and are cut to any length desired.

BEARINGS OF SHAFTING.

In practice, long shafts are scarcely ever entirely free from transverse strains; however, in the parts of long lines, which have no pulleys or gears with the couplings near the bearings, the intervals between the bearings may approach the distances given in the preceding table. The last space should not exceed sixty per cent. of these given, the deflection in that space being much greater than in other parts of the line. In shafts moving with high velocities it will usually be necessary to shorten the distances between the bearings in order to obtain sufficient bearing surface to prevent heating.—[J. B. Francis.

TABLE

OF THE GREATEST ADMISSIBLE DISTANCES BETWEEN THE BEARINGS OF CONTINUOUS SHAFTS, SUBJECT TO NO TRANVERSE STRAIN EXCEPT FROM THEIR OWN WEIGHT.

Diameter of Shaft in inches.	Dist. between bearings in ft.		Diameter of Shaft in inches.	Dist. between bearings in ft.	
	Wrought iron	Steel.		Wrought iron.	Steel.
2	15.46	15.89	6	22.30	22.92
3	17.70	18.19	7	23.48	24.13
4	19.48	20.02	8	24.55	25.23
5	20.99	21.57	9	25.53	26.24

RULES FOR ASCERTAINING THE HORSE POWER OF SHAFTING.

The torsional strength of shafts, or their resistance to breaking by twisting, is proportional to the cube of their diameter. Their stiffness, or resistance to bending, is proportional to the fourth power of their diameters, and varies inversely in proportion to their load and also to the cube of the length of their spans or "bay."

For head shafts supported by bearings close to each side of the main pulley or gear, so as to wholly guard against the transverse strain. The following formula affords an ample margin for strength:—

D=Diameter of shaft in inches.
R=Revolutions per minute.
H=Horse Power.

Cold rolled iron.

(a)
$$H=\frac{D^3\times R}{75}$$
$$D=\sqrt[3]{\frac{75H}{R}}$$

Turned iron.

(b)
$$H=\frac{D^3\times R}{125}$$
$$D=\sqrt[3]{\frac{125H}{R}}$$

Receiving and transmitting pulleys should always be placed as close to bearings as possible, and it is a good practice to frame short "headers" between the main tie-beams of a mill so as to support the main receivers, carried by the head shafts with a bearing close to each side as is contemplated in the formula. But if it is preferred, or necessary, for the shaft to span the full width of the "bay" without intermediate bearings, or for the pulley to be placed away from the bearings towards, or at the middle of the bay, the size of the shaft must be largely increased to secure the stiffness necessary to support the load without undue deflection. Shafts may not deflect more than 1-80 of an inch to each foot of clear length with safety.

To find the diameter of shaft necessary to carry safely the main pulley at the centre of a bay:—

Multiply the fourth power of the diameter obtained by above formula by the length of the bay, and divide this product by the distance from centre to centre of the bearings when the shaft is supported as required by the formula. The fourth root of this quotient will be the diameter required.

The following table, computed by this rule, is practically correct and safe:—

Diam. of shaft given by the formula for head shafts.	Diameter of shaft necessary to carry the load at the centre of a bay which is from centre to centre of bearings.							
	2½ ft.	3 ft.	3½ ft.	4 ft.	5 ft.	6 ft.	8 ft.	10 ft.
Inches.	In.	In.	In.	In.	In.	In.	In.	In.
2	2⅛	2¼	2⅜	2½	2⅝	2¾	2⅞	3
2½	2½	2⅝	2¾	2⅞	3	3⅛	3⅜	3⅝
3	3	3⅛	3¼	3⅜	3½	3¾	4	4¼
3½		3½	3⅝	3¾	4	4¼	4½	4¾
4		4	4⅛	4¼	4½	4¾	5⅛	5⅜
4½			4½	4⅝	4⅞	5⅛	5½	5⅞
5			5	5⅛	5⅜	5⅝	6	6½
5½				5½	5¾	6	6½	6⅞
6				6	6⅜	6⅝	7⅛	7½

As the strain upon a shaft from a load upon it is proportional to the product of the parts of the shaft multiplied into each other; therefore, should the load be applied near one end of the span or bay, instead of at the centre, multiply the fourth power of the diameter of the shaft required to carry the load at the centre of the span or bay by the product of the two parts of the shaft where the load is near one end, and divide this product by the product of the two parts of the shaft when the load is carried at the centre. The fourth root of this quotient will be the diameter required.

Suppose, for example, that a shaft, to carry a certain load at the centre of an 8 feet bay is 4½ inches diameter, then: to carry the same load at a point 2 feet from one end.

$$\frac{(2\times6)\times410}{(4\times4)}=\sqrt[4]{307}=4\ \text{3-16in.}$$

For line shafting from which power is taken at intervals. Bearings 8 feet apart.

Cold rolled iron.	Turned iron.
(c) $H=\dfrac{D^3\times R}{50}$	(d) $H=\dfrac{D^3\times R}{90}$
$D=\sqrt[3]{\dfrac{50H}{R}}$	$D=\sqrt[3]{\dfrac{90H}{R}}$

The shaft in a line which carries the receiving pulley, or which carries a transmitting pulley to drive another line, should always be considered a "head shaft," and should be of the size given by the rules for shafts carrying main pulleys or gears.

For simply transmitting power and short counters:—

Cold rolled iron.

(e) $$H=\frac{D^3\times R}{30}$$

$$D=\sqrt[3]{\frac{30H}{R}}$$

Turned iron.

(f) $$H=\frac{D^3\times R}{50}$$

$$D=\sqrt[3]{\frac{50H}{R}}$$

It is proper to say that some engineers (especially in cotton-mill practice) require from shafting much larger duty than the above formula gives. Under favorable conditions this is admissible, but for ordinary practice we believe that the sizes obtained by these formulas are as light as should be used.

TABLE.

TRANSMITTING EFFICIENCY OF COLD ROLLED IRON SHAFTING AT DIFFERENT SPEEDS. AS PRIME MOVER OR HEAD SHAFT CARRYING MAIN DRIVING PULLEY OR GEAR, WELL SUPPORTED BY BEARINGS.

(Calculated by formula *a*, page 71.)

Diam. of Shaft.	Number of revolutions per minute.										
	60	80	100	125	150	175	200	225	250	275	300
Inches.	H. P.	H. P.	H. P.	H. P.	H. P.	H. P.	H. P.	H. P.	H. P.	H. P.	H. P.
1½	2.7	3.6	4.5	5.6	6.7	7 9	9.0	10	11	12	13
1¾	4.3	5.6	7.1	8.9	10.6	12.4	14.2	16	18	19	21
2	6.4	8.5	10.7	13	16	19	21	24	26	29	32
2¼	9	12	15	19	23	26	30	34	38	42	46
2½	12	17	21	26	31	36	41	47	52	57	62
2¾	16	22	27	35	41	48	55	62	70	76	82
3	21	29	36	45	54	63	72	81	90	98	108
3¼	27	36	45	57	68	80	91	103	114	126	136
3½	34	45	57	71	86	100	114	129	142	157	172
3¾	42	56	70	87	105	123	140	158	174	193	210
4	51	69	85	106	128	149	170	192	212	244	256
4½	73	97	121	151	182	212	243	273	302	383	364

NOTE. The tables and explanations in reference to shafting, gearing, belting, etc., introduced here, were taken by permission from Messrs. Jones & Laughlin's book, compiled by C. C. Briggs. It gives very correct and reliable information on those subjects, and will be found useful for reference.

RULES FOR OBTAINING APPROXIMATE WEIGHT OF IRON.

Rule for Round Bars:—Multiply the square of the diameter in inches by the length in feet, and that product by 2.6. The product will be the weight in pounds, nearly.

Rule for Square and Flat Bars:—Multiply the area of the end of the bar in inches by the length in feet, and that by 3.32. The product will be the weight in pounds, nearly.

TABLE.

TRANSMITTING EFFICIENCY OF TURNED IRON SHAFTING AT DIFFERENT SPEEDS. AS PRIME MOVER OR HEAD SHAFT CARRYING MAIN DRIVING PULLEY OR GEAR, WELL SUPPORTED BY BEARINGS.

(Calculated by formula *b*, page 71.)

Diam. of Shaft.	Number of revolutions per minute.										
	60	80	100	125	150	175	200	225	250	275	300
Inches.	H. P.	H. P.	H. P.	H. P.	H. P.	H. P.	H. P.	H. P.	H. P.	H. P.	H. P.
1¾	2.6	3.4	4.3	5.4	6.4	7.5	8.6	9.7	10.7	11.8	12.9
2	3.8	5.1	6.4	8	9.6	11.2	12.8	14.4	16	17.6	19.2
2¼	5.4	7.3	8.1	10	12	14	16	18	20	22	24
2½	7.5	10	12.5	15	18	22	25	28	31	34	37
2¾	10	13	16	20	24	28	32	36	40	44	48
3	13	17	20	25	30	35	40	45	50	55	60
3¼	16	22	27	34	40	47	54	61	67	74	81
3½	20	27	34	42	51	59	68	76	85	93	102
3¾	25	33	42	52	63	73	84	94	105	115	126
4	30	41	51	64	76	89	102	115	127	140	153
4½	43	58	72	90	108	126	144	162	180	198	216
5	60	80	100	125	150	175	200	225	250	275	300
5½	80	106	133	166	199	233	266	299	333	366	400

TABLE.

TRANSMITTING EFFICIENCY OF TURNED IRON SHAFTING AT DIFFERENT SPEEDS. AS SECOND MOVERS OR LINE SHAFTING. BEARINGS 8 FEET APART.

(Calculated by formula *d*, page 72.)

Diam. of Shaft.	Number of revolutions per minute.										
	100	125	150	175	200	225	250	275	300	325	350
Inches.	H. P.	H. P.	H. P.	H. P.	H. P.	H. P.	H. P.	H. P.	H. P.	H. P.	H. P.
1¾	6.	7.4	8.9	10.4	11.9	13.4	14.9	16.4	17.9	19.4	20.9
1⅞	7.3	9.1	10.9	12.7	14.5	16.3	18.2	20.	21.8	23.6	25.4
2	8.9	11.1	13.3	15.5	17.7	20.	22.2	24.4	26.6	28.8	31
2⅛	10.6	13.2	15.9	18.5	21.2	23.8	26.5	29.1	31.8	34.4	37
2¼	12.6	15.8	19	22	25	28	31	35	38	41	44
2⅜	15	18	22	26	29	33	37	41	44	48	52
2½	17	21	26	30	34	39	43	47	52	56	60
2¾	23	29	34	40	46	52	58	64	69	75	81
3	30	37	45	52	60	67	75	82	90	97	105
3¼	38	47	57	66	76	85	95	104	114	123	133
3½	47	59	71	83	95	107	119	131	143	155	167
3¾	58	73	88	102	117	132	146	162	176	190	205
4	71	89	107	125	142	160	178	196	218	231	249

RULES FOR CALCULATING SPEED OF PULLEYS.

Problem I. The diameter of the driver and driven being given, to find the number of revolutions of the driven:

RULE.—Multiply the diameter of the driver by its number of revolutions, and divide the product by the diameter of the driven; the quotient will be the number of revolutions.

Problem II. The diameter and revolutions of the driver being given to find the diameter of the driven, that shall make any given number of revolutions in the same time:

RULE.—Multiply the diameter of the driver by its number of revolutions, and divide the product by the number of revolutions of the driven; the quotient will be its diameter.

Problem III. To ascertain the size of the driver:

RULE.—Multiply the diameter of the driven by the number of revolutions you wish to make, and divide the product by the revolutions of the driver; the quotient will be the size of the driver.

The above rules are practically correct. Though, owing to the slip, elasticity, and thickness of the belt, the circumference of the driven seldom runs as fast as the driver,

Belts, like gears, have a pitch-line, or a circumference of uniform motion. This circumference is within the thickness of the belt, and must be considered if pulleys differ greatly in diameter, and a required speed is absolutely necessary.

NOTES ON BELTING.

Don't overtax belts by overloading them, or by running them tighter than necessary.

The whole arrangement of shafting and pulleys should be under the direction of a mechanical engineer or competent machinist. Destruction of machinery and belts, together with unsatisfactory results in the business, is a common experience which may, in most cases, be traced to want of knowledge and care in the arrangements of the machinery, and in the width and style of the belts bought, and in the manner of their use, while the manufacturers of the "outfit" are often blamed for bad results which are caused by the faulty management of the mill-owner himself.

Having properly arranged the machinery for the reception of the belts, the next thing to be determined is the length and width of the belts.

When it is not convenient to measure with a tape line the length required, the following rule will be found of service:

RULE.—Add the diameter of the two pulleys together, divide the result by 2, and multiply the quotient by $3\frac{1}{4}$. then add this product to twice the distance between the centres of the shafts, and you have the length required.

The width of the belt needed depends on three conditions: 1.—The tension of the belt. 2.—The size of the smaller pulley, and the proportion of the surface touched by the belt. 3.—The speed of the belt.

The working adhesion of a belt to the pulley will be in proportion both to the number of square inches of belt contact with the surface of the pulley, and also to the arc of the circumference of the pulley touched by

the belt. This adhesion forms the basis of all right calculation in ascertaining the width of belt necessary to transmit a given horse power.

In the location of shafts that are to be connected with each other by belts, care should be taken to secure a proper distance one from the other. It is not easy to give a definite rule as to what this distance should be. Circumstances, generally, have much to do with the arrangement, and the engineer or machinist must use his judgment, making all things conform, as far as may be, to general principles. This distance should be such as to allow of a gentle sag to the belt when in motion.

A general rule may be stated thus:

RULE.—Where narrow belts are to be run over small pulleys—15 feet is a good average—the belt having a sag of 1½ to 2 inches.

For larger belts, working on larger pulleys, a distance of 20 to 25 feet does well, with a sag of 2½ to 4 inches.

For main belts, working on very large pulleys, the distance should be 25 to 30 feet, the belts working well with a sag of 4 to 5 inches.

If too great a distance is attempted, the weight of the belt will produce a very heavy sag, drawing so hard upon the shaft as to produce great friction in the bearings, while at the same time the belt will have an unsteady flapping motion, which will destroy both the belt and machinery.

If possible to avoid it, connected shafts should never be placed one directly over the other, as in such case the belt must be kept very tight to do the work. For this purpose, belts should be carefully selected of well-stretched leather.

It is desirable that the angle of the belt with the floor should not exceed 45°. It is also desirable to locate the shafting and machinery so that belts should run off from each shaft in opposite directions, as this arrangement will relieve the bearings from the friction that would result when the belts all pull one way on the shaft.

The diameter of the pulleys should be as large as can be admitted, provided they will not produce a speed of more than 3750 feet of belt motion per minute. Some authorities limit this speed to 3000.

The pulleys should be a little wider than the belt required for the work.

The motion of driving should run with and not against the laps of the belts.

Tightening or guide pulleys should be applied to the slack side of belts and near the smaller pulley.

Quick-motion belts should be made as straight and as uniform in section and density as possible, and endless if practicable, that is, with permanent joints.

Belts which run loose will, of course, last much longer than those which must be drawn tightly to drive—tightness being evidence of overwork and disproportion.

Never add to the work of a belt so much as to overload it.

The transmitting power of a double bolt is to that of single belt as 10 is to 7. In ordering pulleys, the kind of belt to be used should always be specified.

The strongest part of belt leather is near the flesh side, about ⅓ the way through from that side. It is therefore desirable to run the grain (hair) side on the pulley, in order that the strongest part of the belt may be subject to the least wear.

The flesh side is not liable to crack, as the grain side will do when the belt is old, hence it is better to crimp the grain than to stretch it.

Leather belts run with grain side to the pulley will drive 30 per cent. more than if run with flesh side. The belt, as well as the pulley, adheres

best when smooth, and the grain side adheres best because it is smoothest.

A belt adheres much better and is less liable to slip when at a quick speed than at a slow speed. Therefore it is better to gear a mill with small pulleys and run them at a high velocity than with large pulleys and to run them slower. A mill thus geared costs less and has a much neater appearance than with large heavy pulleys.

Belts should be kept clean and free from accumulations of dust and grease, and particularly from contact with lubricating oils, some of which permanently injure leather.

Leather belts must be well protected against water, and even moisture.

India-rubber is the proper substance for belts exposed to the weather, as it does not absorb moisture and stretch and decay.

Belts should be kept soft and pliable.

TIGHT BELTS.

Clamps with powerful screws are often used to put on belts with extreme tightness, and with most injurious strain upon the leather. They should be very judiciously used for horizontal belts, which should be allowed sufficient slackness to move with a loose, undulating vibration on the returning side, as a test that they have no more strain imposed than is necessary simply to transmit the power.

On this subject, the following from a New England cotton mill engineer of high reputation and large experience is entitled to careful consideration:

"I believe that three-quarters of the trouble experienced in broken pulleys, hot boxes, etc., can be traced to the fault of tight belts. The enormous and useless pressure thus put upon pulleys must in time break them, if they are made in any reasonable proportions, besides wearing out the whole outfit, and causing heating and consequent destruction of the bearings. If manufacturers realized how much this fault of tight belts cost them, in running their mills, probably they would 'wake up.'"

Below are some figures showing the power it takes in average modern mills with first-class shafting, to drive the shafting alone:

Mill		Horse power.		Horse power.		Per cent. of whole.
No. 1.	Whole load	=199	Shafting alone	= 51	or	25.6
" 2.	"	=472	"	=111.5	"	23.6
" 3.	"	=486	"	=134	"	27.5
" 4.	"	=677	"	=190	"	28.1
" 5.	"	=759	"	=172.6	"	22.7
" 6.	"	=235	"	= 84.8	"	36.1
" 7.	"	=670	"	=262.9	"	39.2
" 8.	"	=677	"	=182	"	26.8

These may be taken as a fair showing of the power that is required in many of our best (not worst) mills to drive shafting. It will be seen that the percentage is large—from 22 per cent. upwards. It is unreasonable to think that all that power is consumed by a legitimate amount of friction of bearings and belts. It is out of all reason, and I know of no cause for such a loss of power but *tight belts*. These, when there are hundreds or thousands in a mill, easily multiply the friction on the bearings and would account for the figures. Taking the cost of a H. P. at 35 lbs. of coal per day per H. P., and allowing 15 per cent. of the whole load as a reasonable

loss from friction, one can see that the cost of running tight belts is no inconsiderate one—to say nothing about the loss resulting from the shortened life of the entire equipment."

Rules for Calculating the Horse Power which can be Transmitted by Belting.

No rules can be given which will apply to all cases. Circumstances and conditions must and will modify them. Belts, for instance, for machines which are frequently stopped and started, and shifting belts, must be wider, to stand the wear and tear and to overcome the starting friction, than belts which run steadily and uninterruptedly. For belts, however, running under ordinarily favorable conditions, the rules given below may be regarded as safe and reliable.

The average thickness of single belts is 3-16 of an inch, and when made of good ox-hide, well tanned, their breaking strength per inch of width has been determined as follows:

In the solid leather,	- -	675 lbs.
At the rivet holes of splices,	-	362 "
At the lacing holes,	- -	210 "

The safe working tension is assumed to be 45 lbs. per inch of width, which is equal to a velocity of about 60 square feet per minute per horse power, which is safe practice for single belts in good condition.

C=circumference, in inches of pulley.
D=diameter, " "
R=revolutions per minute, "
W=width of belt in inches.
H=horse power that can be transmitted by the belt.

Then:—To find the horse power a single belt can transmit, the size of the pulley and width of the belt being given:

$$H=\frac{C\times R\times W}{144\times 60} \quad \text{or,} \quad H=\frac{C\times R\times W}{8640} \quad \text{or,}$$

to simplify the process, substituting D for C, and dividing the constant 8640 by 3.1416, the proportion of circumference to diameter, the formula would be

$$H=\frac{D\times R\times W}{2750}$$

The transmitting efficiency of double belts of average thickness is to that of single belts as 10 is to 7; therefore, for double belts the formula would be:

$$H=\frac{D\times R\times W}{1925}$$

The horse power to be transmitted and the size of the pulley being given, to find the width of the belt required:

Single Belt.	Double Belt.
$W=\frac{H\times 2750}{D\times R}$	$W=\frac{H\times 1925}{D\times R}$

The horse power and width of belt being given, to find the diameter of pulley:

Single Belt.	Double Belt.
$D=\dfrac{H\times 2750}{R\times W}$	$D=\dfrac{H\times 1925}{R\times W}$

The horse power, diameter of the pulley and width of belt being given, to find the number of revolutions necessary:

Single Belt.	Double Belt.
$R=\dfrac{H\times 2750}{D\times W}$	$R=\dfrac{H\times 1925}{D\times W}$

In these rules it has been assumed that the belts are open, the pulleys of equal diameters, and the arc of contact is the semi-circumference. If, however, the pulleys are of different diameters and the arc of the contact is less than the semi-circumference, the rules must be modified accordingly.

If a belt is crossed and the arc of contact is greater than the semi-circumference, of course more power could be transmitted by the pulley; but only by increasing the tension so as to overtax the belt.

By multiplying the constant for the semi-circumference, by the ratios of frictions and pressure in the third column of the following table, the constant for every case likely to occur in practice, are obtained.

When the arc of contact of the smaller pulley is:

Degrees.		Circumference.	Ratio.	Constant. Sin. B.	Constant. Dou. B.
90	or,	¼ =.25	2.21	6080	4250
112½	"	5-16=.312	1.72	4730	3310
120	"	⅓ =.333	1.6	4400	3080
135	"	⅜ =.375	1.4	3850	2700
150	"	5-12=.417	1.24	3410	2390
157½	"	7-16=.437	1.17	3220	2250
180 to 270		½ =.5 to ¾ =.75	1.	2750	1925

The following tables, computed by the rules given above for semi-circumference, will be found useful and convenient.

When the diameters of the pulleys are different: Determine the arc of contact of the belt with the smaller pulley and divide the horse power given in the table by the ratio corresponding to the arc, as given in column three of preceding table.

TABLE

OF HORSE POWER WHICH MAY BE TRANSMITTED BY OPEN SINGLE BELTS TO PULLEYS RUNNING 100 REVOLUTIONS PER MINUTE. THE DIAMETERS OF THE DRIVING AND DRIVEN PULLEY BEING EQUAL.

The horse power of double belts is 10-7 of that given in the table.

Diam. of pulley.	Width of belt in inches.							
	2	2½	3	3½	4	4½	5	6
Inches.	H. P.	H. P	H. P.	H. P.	H. P.	H. P.	H. P.	H. P.
6	.44	.54	.65	.76	.87	.98	1.09	1.31
6½	.47	.59	.71	.83	.95	1.07	1.19	1.42
7	.51	.64	.76	.89	1.01	1.14	1.27	1.53
7½	.55	.68	.82	.95	1.09	1.23	1.36	1.64
8	.58	.73	.87	1.02	1.16	1.31	1.45	1.75
8½	.62	.77	.93	1.08	1.24	1.39	1.55	1.86
9	.65	.82	.98	1.15	1.31	1.48	1.64	1.97
9½	.69	.86	1.04	1.21	1.39	1.56	1.74	2.08
10	.73	.91	1.09	1.27	1.45	1.63	1.81	2.18
11	.8	1.	1.2	1.4	1.6	1.8	2.	2.4
12	.87	1.09	1.31	1.53	1.75	1.97	2.18	2.62
13	.95	1.18	1.42	1.65	1.89	2.12	2.36	2.83
14	1.02	1.27	1.52	1.77	2.02	2.27	2.53	3.05
15	1.09	1.36	1.64	1.91	2.19	2.46	2.73	3.29
16	1.16	1.45	1.74	2.03	2.32	2.61	2.91	3.48
17	1.24	1.55	1.85	2.16	2.47	2.78	3.09	3.70
18	1.31	1.64	1.96	2.29	2.62	2.95	3.27	3.92
19	1.39	1.73	2.07	2.42	2.76	3.11	3.45	4.14
20	1.45	1.82	2.18	2.55	2.91	3.27	3.64	4.36
21	1.52	1.91	2.29	2.67	3 05	3.44	3 82	4.58
22	1.6	2.	2.4	2.8	3.2	3.6	4.	4.8
23	1.67	2.09	2.51	2.93	3.35	3.75	4.18	5.02
	4	5	6	8	10	12	14	16
24	3.5	4.4	5.2	7.	8.7	10.5	12.2	14.
25	3.6	4.5	5.5	7.3	9.1	10.9	12.7	14.5
26	3.8	4.7	5.7	7.6	9.5	11.3	13.2	15.1
27	3.9	4.9	5.9	7.8	9.8	11.8	13.7	15.6
28	4.1	5.1	6.1	8.1	10.2	12.2	14.3	16.3
29	4.2	5.3	6.3	8.4	10.5	12.6	14.8	16.9
30	4.4	5.4	6.6	8.7	10.9	13.1	15.3	17.4
31	4.5	5.6	6.8	9.	11.3	13.5	15.8	18.
32	4.7	5.8	7.	9.3	11.6	14.	16.3	18.6
33	4.8	6.	7.2	9.6	12.	14.4	16.8	19.2
34	4.9	6.2	7.4	9.9	12.4	14.8	17.3	19.8
35	5.1	6.4	7.6	10.2	12.7	15.3	17.9	20.4
36	5.2	6.5	7.8	10.5	13.1	15.7	18.3	20.9
37	5.4	6.7	8.1	10 8	13.5	16.2	18.9	21.5
38	5.5	6.9	8.3	11.	13.8	16.6	19.3	22.1
39	5.7	7.1	8.5	11.3	14.2	17.	19.9	22.7
40	5.8	7.3	8.7	11.6	14.6	17.5	20.4	23 3
42	6.1	7.6	9.2	12.2	15.3	18.2	21.4	24.3
44	6.4	8.	9.6	12.8	16.	19.2	22.4	25.6

TABLE OF HORSE POWER OF SINGLE BELTS.—Continued.

Diam. of pulley.	Width of belt in inches.							
	4	5	6	8	10	12	14	16
Inches.	H. P.	H. P.	H. P.	H. P.	H. P.	H. P.	H. P.	H. P.
46	6.7	8.4	10.	13.4	16.	20.1	23.4	26.8
48	7.	8.8	10.4	14.	17.4	21.	24.4	28.
50	7.2	9.	10.9	14.6	18.2	21.8	25.4	29.
54	7.8	9.8	11.8	15.6	19.6	23.6	26.4	31.2
60	8.8	10.8	13.1	17.4	21.8	26.2	30.6	34.8
66	9.6	12.	14.4	19.2	24.	28.8	33.6	38.4
72	10.4	13.	15.6	21.	26.2	31.4	36.6	41.8
78	11.4	14.2	17.	22.6	28.4	34.	39.8	45.4
84	12.2	15.2	19.4	24.4	30.6	36.4	42.8	48.6
	18	20	22	24	26	28	30	32
24	16	17	19	21	23	24	26	28
30	19	22	24	26	28	31	33	35
36	24	26	29	31	34	37	39	42
38	25	28	30	33	36	39	41	44
40	26	29	32	35	38	41	44	47
42	28	31	34	36	40	43	46	49
44	29	32	35	38	42	45	48	51
48	31	35	38	42	45	49	52	56
50	33	36	40	44	47	51	54	58
54	35	39	43	47	50	53	58	62
60	39	44	48	52	57	61	65	70
66	43	48	53	58	62	67	72	77
72	47	52	58	63	68	73	78	84
78	51	57	62	68	74	80	85	91
84	55	61	67	73	79	86	91	97
96	63	70	76	84	90	98	104	112
120	78	88	96	104	114	122	130	140
144	94	104	116	126	136	146	156	168

TO FIND THE LENGTH OF BELT WHEN CLOSELY ROLLED.

The sum of the diameter of the roll and the eye in inches, multiplied by the number of turns made by the belt, and this product multiplied by the decimal .1309, will equal length of the belt in feet.

TO FIND THE APPROXIMATE WEIGHT OF BELTS.

Multiply the length of the belt, in feet, by the width in inches and divide the product by 13 for single, and 8 for double belt.

GEARING.

In general, the term "gearing" is applied to all parts of machinery by which motion is transmitted; especially is it employed for wheels—whether friction or tooth. Tooth wheels are "in gear" when their teeth are engaged together; "out of gear" when separated.

Spur gears are wheels with the teeth or cogs ranged round the outer or inner surface of the rim, in the direction of radii from the centre,

and their action may be regarded as that of two cylinders rolling upon one another.

Bevel gears are wheels, the teeth of which are placed upon the outer periphery in a direction converging to the apex of a cone—and their action is similar to that of two cones rolling upon each other. When two bevel wheels of same diameter work together at an angle of 45° they are called "mitre wheels.

The teeth are called "teeth" when they are of one and the same piece as the body of the wheel, and "cogs" when they are of separate material. Wheels in whose rim "cogs" are inserted are called mortise wheels.

The straight line drawn from centre to centre of a pair of wheels is called the "line of centres."

The pitch-line, by which the size of a wheel is always given, represents as noted above, the touching of two cylinders rolling upon one another, and is the line or circle on which the "pitch" of teeth is measured.

The pitch is distance between the centres of two adjacent teeth measured at the pitch-line.

PROPORTIONS FOR GEAR WHEELS.

P=pitch—in inches.
D=diameter of pitch circle, in inches.
a =height of tooth from pitch circle to face of tooth.
b =height of tooth from pitch circle to root of tooth.
c =thickness of tooth, in inches.
d =thickness of rim, in inches.
f =thickness of arms, if flat.
B=breadth of teeth, in inches.
N=number of teeth in the wheel.
R=revolutions of wheel per minute.
H=horse power that can be transmitted by the wheel.

$a=P\times 0.32$	$b=P\times 0.38$
$c=P\times 0.48$ when cast	$d=P\times 0.45$
$e=P\times 0.5$ when cut	$f=P\times 0.45$

Mortise wheels to be wider than iron wheels by $P\times 0.9$, and thickness of rim double that of iron wheels.

$$D=0.32\times P\times N.$$

$$H=\frac{P\times D\times B\times R}{550}$$

In calculating the speed of gears, multiply or divide, as the case may be, by the number of teeth (instead of diameter as for pulleys), and use the rule on page 75.

DIAMETRAL AND CIRCULAR PITCH.

Diametral pitch is the number of teeth to one inch of diameter of pitch line or circle.

Circular pitch is the distance from centre to centre of two adjacent teeth on the pitch-line.

No. 1 table shows the diametral pitches with the corresponding circular pitches.

No. 2 table shows the circular pitches with the corresponding diametral pitches.

TABLE No. 1.		TABLE No. 2.	
Diam. Pitch.	Circular Pitch.	Circular Pitch.	Diam. Pitch.
2	1.57	1¾ inch	1.79
2¼	1.39	1½ "	2.09
2½	1.25	1 7-16 "	2.18
2¾	1.14	1⅜ "	2.28
3	1.04	1 5-16 "	2.39
3½	.890	1¼ "	2.51
4	.785	1 3-16 "	2.66
5	.628	1⅛ "	2.79
6	.523	1 1-16 "	2.96
7	.448	1 "	3.14
8	.392	15-16 "	3.35
9	.350	⅞ "	3.59
10	.314	13-16 "	3.86
11	.280	¾ "	4.19
12	.261	11-16 "	4.57
14	.224	⅝ "	5.03
16	.196	9-16 "	5.58
18	.174	½ "	6.28
20	.157	7-16 "	7.18
22	.143	⅜ "	8.38
24	.130	5-16 "	10.06
26	.120	¼ "	12.56
28	.112	3-16 "	16.75

NOTES ON THE USE OF WIRE ROPE.

Two kinds of wire rope are manufactured. The most pliable variety contains 19 wires in the strand, and is generally used for hoisting and running rope.

For safe working load, allow 1-5 or 1-7 of the ultimate strength, according to speed, so as to get good wear from the rope. Wire rope is as pliable as new hemp rope of the same strength; but the greater the diameter of the sheaves the longer the wire rope will last.

Experience has proved that the wear increases with the speed. It is, therefore, better to increase the load than the speed. Wire rope must not be coiled or uncoiled like hemp or manilla—all untwisting or kinking must be avoided.

In no case should galvanized rope be used for running. One day's use scrapes off the zinc coating.—[Roebling.

TABLE OF STRAINS PRODUCED BY LOADS ON INCLINED PLANES.

Elevation in 100 feet.	Strain in lbs.on r'pe from load of 1 ton.	Elevation in 100 feet.	Strain in lbs.on r'pe from load of 1 ton.	Elevation in 100 feet.	Strain in lbs.on r'pe from load of 1 ton.	Elevation in 100 feet.	Strain in lbs.on r'pe from load of 1 ton.
ft. deg.		ft. deg.		ft. deg.		ft. deg.	
10=5½	112	50=26⅓	905	90=42	1347	130=52½	1592
20=11 1-5	404	60=31	1040	100=45	1419	140=54½	1633
30=16¾	586	70=35	1156	110=47¾	1487	150=56¼	1671
40=21 5-6	754	80=38⅔	1260	120=50¼	1544	160=58	1708

TABLE

OF TRANSMISSION AND HOISTING ROPES WITH NINETEEN WIRES TO THE STRAND—IRON.

Trade No.	Circumference in inches.	Diameter.	Weight p'r ft. in lbs. of rope with h'mp Cen.	Breaking strain in tons of 2000 lbs.	Proper work-load in tons of 2000 lbs.	Circumference of hemp r'pe of equal strength.	Min. size of drum or sh've in ft
1	6¾	2¼	7.80	74	15	15½	8
2	6	2	6.02	65	13	14½	7
3	5½	1¾	5.08	54	11	13	6½
4	5	1⅝	4.10	44	9	12	5
5	4⅜	1½	3.10	35	7	10¾	4½
6	4	1¼	2.44	27	5½	9½	4
7	3½	1⅛	1.95	20	4	8	3½
8	3⅛	1	1.50	16	3	7	3
9	2¾	⅞	1.14	11½	2½	6	2¾
10	2¼	¾	0.83	8.64	1¾	5	2½
10¼	2	⅝	0.65	5.13	1¼	4½	2
10½	1⅝	9-16	0.44	4.27	¾	4	1¾
10¾	1½	½	0.35	3.48	½	3½	1½

WROUGHT IRON, USUALLY ASSUMED.

A cubic foot, =480 lbs.
A bar 1 in. square, 1 ft. long= 3⅓ "
A square foot, 1 inch thick =40 lbs.
A bar 1 in. sq., 1 yd. long =10 "

To find the weight of cast iron balls when the diameter is given:
RULE.—Multiply the cube of the diameter by .1377.

To find the diameter of cast iron balls when the weight is given:
RULE:—Multiply the cube of the weight by 1.936.

To find the weight of a spherical shell:
RULE:—From the weight of a ball of the outer diameter subtract the weight of one of the inner diameters.

TO CONVERT THE WEIGHT OF

Wrought iron	into	cast	iron	×0.928
"	"	"	steel	×1.014
"	"	"	zinc	×0.918
"	"	"	brass	×1.082
"	"	"	copper	×1.144
"	"	"	lead	×1.468

DECIMAL APPROXIMATIONS USEFUL IN CALCULATIONS.

Cubic	ins.,	×.263 =	lbs. av.	cast iron.
"	"	×.281 =	"	wrought iron.
"	"	×.283 =	"	cast steel.
"	"	×.3225=	"	copper.
"	"	×.3037=	"	brass.
"	"	×.26 =	"	zinc.
"	"	×.4103=	"	lead.
"	"	×.2666=	"	tin.
"	"	×.4908=	"	mercury.

Cylin. ins., ×.2065= lbs. av. cast iron.
" " ×.2168= " wrought iron.
" " ×.2223= " cast steel.
" " ×.2533= " copper.
" " ×.2385= " brass.
" " ×.2042= " zinc.
" " ×.3223= " lead.
" " ×.207 = " tin.
" " ×.3854= " mercury.

Specific Gravity.

Cast iron, - - - - -	average	7.21
Wrought iron, - - -	"	7.78
Cast steel, - - - -	"	7.85
Bessemer steel - - -	"	7.86

Light iron indicates impurity.
The heaviest steel contains least carbon.

TABLE

Of Transmission of Power by Wire Ropes.

Showing necessary size and speed of wheels and rope to obtain any desired amount of power.—[Roebling.

Diam. of Wh'l in ft.	No. of Revolut's.	Diam. of Rope.	Horse Power.	Diam. of Wh'l in ft.	No. of Revolut's.	Diam. of Rope.	Horse Power.
4	80	3/8	3.3	10	80	11-16	58.4
	100	3/8	4.1		100	11-16	73.
	120	3/8	5.		120	11-16	87.6
	140	3/8	5.8		140	11-16	102.2
5	80	7-16	6.9	11	80	11-16	75.5
	100	7-16	8.6		100	11-16	94.4
	120	7-16	10.3		120	11-16	113.3
	140	7-16	12.1		140	11-16	132.1
6	80	1/2	10.7	12	80	3/4	99.3
	100	1/2	13.4		100	3/4	124.1
	120	1/2	16.1		120	3/4	148.9
	140	1/2	18.7		140	3/4	173.7
7	80	9-16	16.9	13	80	3/4	122.6
	100	9-16	21.1		100	3/4	153.2
	120	9-16	25.3		120	3/4	183.9
8	80	5/8	22.	14	80	7/8	148.
	100	5/8	27.5		100	7/8	185.
	120	5/8	33.		120	7/8	222.
9	80	5/8	41.5	15	80	7/8	217.
	100	5/8	51.9		100	7/8	259.
	120	5/8	62.2		120	7/8	300.

PLATE IRON.

WEIGHT OF SUPERFICIAL FOOT.

Thickness in Inches.	Weight in Pounds.	Thcknessi in Inches.	Weight in Pounds.
1-32=.03725	1.25	5-16=.3125	12.58
1-16=.0625	2.519	⅜=.375	15.10
3-32=.0937	3.788	7-16=.4375	17.65
⅛=.125	5.054	½=.5	20 20
5-32=.1562	6.305	9-16=.5625	22.76
3-16=.1875	7 578	⅝=.625	25.16
7-32=.2187	8.19	¾=.75	30.20
¼=.25	10.09	⅞=.875	35.30
9-32=.2812	11.38	1=.1	40.40

To ascertain the weight of plate iron for rectangular sheets:

RULE:—Multiply the product of the length by breadth in inches, by one of the following decimals, according to thickness, and the product will be the weight required.

3-16	thick	×.0526	9-16	thick	×.158
¼	"	×.07	⅝	"	×.1748
5-16	"	×.0874	¾	"	×.2096
⅜	"	×.1048	⅞	"	×.2452
7-16	"	×.1226	1	"	×.28
½	"	×.14			

FOR CIRCULAR SHEETS.

RULE:—Multiply the square of the diameter by one of the following decimals:

3-16	thick	×.0414	9-16	thick	×.124
¼	"	×.055	⅝	"	×.1372
5-16	"	×.0686	¾	"	×.1646
⅜	"	×.0823	⅞	"	×.1924
7-16	"	×.0962	1	"	×.22
½	"	×.11			

RIVETS AND RIVETING.

Dr. Fairbairn estimates the strength of a joint, single riveted, according to the proportions of the following table at .56 that of one of the solid plates; and the strength of a double-riveted one at .7 that of one solid plate.

Rivet holes for important work should be drilled, not punched. There is no doubt that when the punching is carelessly done, the loss of strength is greater than that shown above.

Kirkaldy's experiments show that the shearing strain of steel rivets is one-fourth less than their tensile strength—and that the proportions of iron rivets are too small when steel rivets are used for steel plates.

Dr. Fairbairn gives, as reliable in practice, the following.

TABLE

For Proportioning the Riveting for Steam and Water-Tight Joints for Iron Plates.

Thickness of each plate.	Diameter of Rivets.	Length of Rivets.	Cen. to cen. of Rivets.	Lap in single Riveting.	Lap in double Riveting.
Inches	Inches	Inches	Inches	Inches	Inches
3-16	⅜	⅞	1¼	1¼	21-16
¼	½	1⅛	1½	1½	2½
5-16	⅝	1⅜	1⅝	1⅞	31-16
⅜	¾	1⅝	1¾	2	3⅜
½	13-16	2¼	2	2¼	3¾
⅝	15-16	2¾	2½	2¼	4⅝
¾	1⅛	3¼	3	3¾	5½

These give diameter of rivet=1¾ thickness of one plate; length of rivet 2.6 diams.; distance from centre to centre 3 diams. For steel plates the proportions are too small.

WEIGHT OF CIRCULAR BOILER HEADS.

Diam. in Inches.	Thickness of Iron—Inches.						
	3-16	1-4	5-16	3-8	7-16	1-2	9-16
16	11	14	18	21	25	28	32
18	13	18	22	27	31	36	40
20	17	22	27	33	38	44	50
22	20	27	33	40	47	54	60
24	24	32	40	47	55	64	71
26	28	37	46	56	64	75	84
28	32	43	53	65	75	86	97
30	37	50	62	74	87	100	112
32	42	56	70	84	99	112	127
34	48	64	79	96	111	128	143
36	54	71	89	108	125	142	161
38	60	79	99	120	139	158	179
40	66	88	110	132	154	176	198
42	73	97	121	146	170	194	220
44	80	107	133	160	187	214	240
46	88	117	145	176	204	234	262
48	95	127	158	190	222	254	286
50	103	138	172	206	241	276	310
52	112	149	186	224	260	298	335
54	121	160	200	242	281	320	362
56	130	172	214	260	302	344	389
58	139	185	231	278	324	370	417
60	149	198	247	298	336	396	446

Kirkaldy says: The breaking strain of iron and puddled steel plates is greater in the direction in which they have been rolled than in the direction of their breadth; but in cast steel the reverse.

ROUND CAST IRON.—WEIGHT, LINEAL FOOT.

Diam. Inches.	Weight. Pounds.	Diam. Inches.	Weight. Pounds.	Diam. Inches.	Weight. Pounds.	Diam. Inches.	Weight. Pounds.
1	2.45	4	39.27	7	120.26	11	296.98
1¼	3.84	4¼	44.33	7¼	129.01	11½	324.59
1½	5.52	4½	49.70	7½	138.06	12	353.43
1¾	7.52	4¾	55.88	7¾	147.42	13	414.79
2	9.82	5	61.36	8	157.08	14	481.06
2¼	12.43	5¼	67.65	8¼	167.05	15	552.23
2½	15.34	5½	74.25	8½	177.33	16	628.32
2¾	18.56	5¾	81.15	8¾	187.91	17	709.31
3	22.09	6	88.36	9	198.80	18	795.22
3¼	25.92	6¼	95.87	9½	221.51	20	981.75
3½	30.07	6½	103.70	10	245.44	22	1187.92
3¾	34.52	6¾	111.83	10½	270.60	24	1413.72

WROUGHT IRON WELDED TUBES.

FOR STEAM, GAS, OR WATER.

One-eighth to 1 inch, inclusive, Butt-Welded. Tested to 300 lbs. per sq. inch, hydraulic pressure.

One and three-fourths inch and upwards, Lap-Welded. Tested to 500 lbs. per sq. inch, hydraulic pressure.

Nominal size.	Outside Diam. Standard.	Inside Diam. Standard.	Weight per foot. Lbs.	Threads to in. of screw.	Inside area sq. inches.
⅛	.40	.27	.24	27	.0572
¼	.54	.36	.42	18	.1018
⅜	.67	.49	.56	18	.1886
½	.84	.62	.85	14	.3019
¾	1.05	.82	1.12	14	.5281
1	1.31	1.04	1.67	11½	.8495
1¼	1.66	1.38	2.25	11½	1.4957
1½	1.90	1.61	2.69	11½	2.0358
2	2.37	2.06	3.66	11½	3.3329
2½	2.87	2.46	5.77	8	4.7529
3	3.50	3.06	7.54	8	7.3529
3½	4.00	3.54	9.05	8	9.8423
4	4.50	4.02	10.72	8	12.0924
4½	5.00	4.50	12.49	8	15.9043
5	5.56	5.04	14.56	8	19.9504
6	6.62	6.06	18.77	8	28.8426
7	7.62	7.02	23.41	8	38.7048
8	8.62	7.98	28.35	8	50.0146
9	9.68	9.00	34.07	8	63.6174
10	10.75	10.01	40.64	8	80.1186

RULE FOR STRENGTH OF CYLINDER BOILERS.

S=tensile strength of the iron. T=thickness of plate, in inches.
D=Diameter of shell, in inches. P=bursting pressure.

Then $P=\dfrac{T \times S}{D} \times 2$, and $T=\dfrac{P \times D}{S \times 2}$

Working strain allowed by U. S. laws for single-riveted boilers 1-6, and for double-riveted boilers 1-5 the bursting pressure.

TABLE

Of Lap-Welded American Charcoal Iron Boiler Tubes.

External diameter.	Internal diameter.	Thickness.	Length pipe per sq. ft. of outside sur'ce	Internal area.	External area.	Weight per foot.
In.	In.	In.	Feet.	In.	In.	Lbs.
1	.856	.072	3.816	0.575	0.785	0.7
1¼	1.106	.072	3.056	0.960	1.227	0.9
1½	1.384	.083	2.547	1.396	1.767	1.25
1¾	1.560	.095	2.183	1.911	2.405	1.66
2	1.804	.098	1.909	2.556	3.142	1.98
2¼	2.054	.098	1.698	3.314	3.976	2.23
2½	2.283	.109	1 528	4.094	4.939	2.75
2¾	2.533	.109	1.390	5.039	5.940	3.04
3	2.783	.109	1.273	6.083	7.069	3.33
3¼	3.012	.119	1.175	7.125	8.296	3.95
3½	3.262	.119	1.091	8.357	9.621	4.27
3¾	3.512	.119	1.018	9.687	11.045	4.59
4	3.741	.130	0.955	10.992	12 566	5.32
4½	4.241	.130	0.849	14.126	15.904	6.01
5	4.72	.140	0.764	17.497	19.635	7.22
6	5.699	.151	0.687	25.509	28.274	9.84

U. S. STANDARD SCREW THREADS.

Diam. of screw.	Thread per inch.	Diam. at root of thread.	Diam. of screw.	Thread per inch.	Diam. at root of thread.
¼	20	.185	2	4½	1.712
5-16	18	.240	2¼	4½	1.962
⅜	16	.294	2½	4	2.175
7-16	14	.344	2¾	4	2.425
½	13	.400	3	3½	2.628
9-16	12	.454	3¼	3½	2.878
⅝	11	.507	3½	3¼	3.100
¾	10	.620	3¾	3	3.317
⅞	9	.731	4	3	3 566
1	8	.837	4¼	2⅞	3.825
1⅛	7	.940	4½	2¾	4.027
1¼	7	1.065	4¾	2⅝	4.255
1⅜	6	1.160	5	2½	4.480
1½	6	1.284	5¼	2½	4.730
1⅝	5½	1.389	5½	2⅜	5.053
1¾	5	1.490	5¾	2⅜	5.203
1⅞	5	1.615	6	2¼	5.423

Angle of thread 60°. Flat at top and bottom ⅛ of pitch.

WHITWORTH'S GAS-THREADS.

Diameter in inches.	⅛	¼	⅜	½	¾	1 to 2
No. thread to inch.	28	19	19	14	14	11

FLUXES FOR SOLDERING OR WELDING.

Iron or steel.......................... Borax or sal-ammoniac.
Tinned iron.......................... Resin or chloride of zinc.
Copper and brass.................... Sal-ammoniac or chloride of zinc.
Zinc.. Chloride of zinc.
Lead.. Tallow or resin.
Lead and tin pipes..................... Resin and sweet oil.

BRAZING.

The edges filed or scraped clean and bright, covered with spelter and powdered borax, and exposed in a clear fire to a heat sufficient to melt the solder.

ALLOYS.

ALLOYS.	Tin.	Copper.	Zinc.	Antimony.	Lead.	Bismuth.
Brass, engine bearings....................	13	112	¼	....	....	....
Tough brass, engine work....................	15	100	15	....	....	....
" for heavy bearings....................	25	160	5	....	....	....
Yellow brass, for turning....................	....	2	1	....	....	....
Flanges to stand brazing....................	....	32	1	....	1	....
Bell metal....................................	5	16	...	...	...	....
Babbitt's metal....................................	10	1	....	1	....	....
Brass, locomotive bearings....................	7	64	1	....	....	...
" for straps and glands....................	16	130	1	...	....	....
Muntz's sheathing....................................	....	6	4	....	....	....
Metal to expand in cooling....................	....	....	....	2	9	1
Pewter....................................	100	....	....	17	....	....
Spelter....................................	....	1	1	....	....	....
Statuary bronze....................................	2	90	5	....	2	....
Type metal.............................from	....	...	....	1	3	...
" " ....to	....	....	....	1	7	....
SOLDERS.						
For lead....................................	1	....	....	....	1½	....
" tin....................................	1	....	....	....	2	....
" pewter....................................	2	....	....	....	1	....
" brazing (hardest)....................	....	3	1	....	....	....
" " (hard)....................................	....	1	1	....	....	....
" " (soft)....................................	1	4	3	....	...	....
" " " ....or	2	....	....	1	....	....

STRENGTH OF IRON.

Tests by U. S. Ordnance department have determined:

1. That the strength and density of iron are greatly increased by its being continued in fusion, and by its being remelted.
2. That the transverse strength is augmented by rapid cooling in small castings.

3. That the tensile strength is increased by slow cooling in large masses.

Following is the table of Strength of Iron—Charooal Pig Iron.

	By whom tests were made.	No. of sam. tested.		Trans. strength.	Tensile strength.	Specific gravity.
				lbs. per sq. in.	lbs. per sq. in.	
American.	U. S. Ord. Dept.	56	Mean	9,409	27,232	7,302
			Least	8,014	22,402	7,168
			Great.	10,717	31,027	7,402
English.	Brit. Ord. Dept.	51	Mean	7,102	23,257	7,140
			Least	5,538	17,958	7,052
			Great.	9,120	28,960	7,259

The mean strength of American wrought iron is 55,900 lbs.; English 53,900. Ultimate extension of wrought iron is 600th part of its length. The working strain is from 1-6 to ¼ the mean strength.

Resistance to flexure acting evenly over the surface, equals one-half the tensile strength. Bars of wrought iron will expand or contract 151200th of their length for each degree of heat. With range of temperature of this country (=20 to+120°)=140°, will expand or contract 1080th part of its length, equal to a force of 20,740 lbs., or 9¼ tons per square inch of section. Tensile strength increases, in from 1 to 6 reheatings and rollings, from 43,904 lbs. to 60,824 lbs.; in from 6 to 12, is reduced again to 43,904.

To Test Quality of Iron.

If fracture gives long silky fibres of leaden-gray hue, fibres cohering and twisting together before breaking, may be considered a tough, soft iron. A medium even grain mixed with fibres, a good sign. A short, blackish fibre indicates badly refined iron. A very fine grain denotes a hard, steely iron, apt to be cold short, hard to work with the file. Coarse grain with brilliant crystallized fracture, yellow or brown spots, denotes a brittle iron, cold short, working easily when heated, welds easily. Cracks on the edge of bars, sign of hot, short iron. Good iron is readily heated, soft under the hammer, and throws out but few sparks.

All iron contains more or less carbon—the hardest the most.

Note on Forgings.

Iron, while heating, if exposed to air, will oxidize; while at white heat if in contact with coal, will carbonize, or become steely. Iron should be heated as rapidly as possible.

Steel.

Steel is a compound of iron and carbon, varying in proportion of 0.5 per cent. to 5 per cent. of carbon. Specific gravity 7.8; tensile strength, 120,000 lbs. per sq. inch. Ordinary steel is carbon steel, but steely compounds of iron have been produced which have the same general properties as ordinary steel, the carbon of which is replaced by other chemical elements.

Foreign Substances in Iron and Steel.

Silicon is generally excluded as slag, its presence makes iron hard and brittle; but up to .08 per cent, it will do no harm, provided .3 of manganese is present with it.

Sulphur makes iron and steel "red-short."

Phosphorus. .5 to .8 per cent. is sufficient to produce cold-shortness in iron; in steel, phosphorus to an extent of .2 per cent. does not affect the working or hammering of steel.

Manganese. .5 per cent. is sufficient to make iron cold-short; it is valuable in iron to be converted into steel.

Arsenic produces red-shortness in iron—but is valuable in chilling; it increases the hardness in steel at the expense of the toughness.

Copper renders steel red-short.

Tungsten renders steel hard and tenacious.

Vanadium improves the ductility of iron for wire-drawing.

Carbon. .25 per cent. gives malleable iron; .5 per cent. gives steel; 1.75 gives the limit of welding steel; 20 gives the lowest limit of cast iron.

To Test Steel and Iron.

Nitric acid will produce a black spot on steel; the darker the spot the harder the steel. Iron, on the contrary, remains bright if touched with nitric acid. Good steel in its soft state has a curved fracture and a uniform gray lustre; in its hard state a dull, silvery, uniform white. Cracks, threads, or sparkling particles, denote bad quality.

Good steel will not bear a white heat without falling to pieces, and will crumble under the hammer at a bright red heat, while at a middling heat it may be drawn out under the hammer to a fine point.

Tempering Steel.

Color.	Purpose.	Tem.	All'y whose fusing point is same tem.		
		Fah.	Tin.		Lead.
Light straw	Turning tools for metal.	430°	1	to	$1\frac{3}{4}$
Dark straw	Wood tools, taps and dies.	470°	1	to	$2\frac{1}{8}$
Brown yellow	Hatchets, Chip'g chis.	500°	1	to	$4\frac{3}{4}$
Dark purple	Springs, etc.	550°	1	to	12

NOTES ON THE WORKING OF STEEL.

Extract from a Lecture read before the Engineers Society of Western Pennsylvania, by William Metcalf, C. E.

1. Good soft heat is safe to use if steel be immediately and thoroughly worked.

It is a fact that good steel will endure more pounding than any iron.

2. If steel be left long in the fire it will lose its steely nature and grain and partake of the nature of cast iron.

Steel should never be kept hot any longer than is necessary to the work to be done.

3. Steel is entirely mercurial under the action of heat, and a careful study of the table will show that there must of necessity be an injurious internal strain created, whenever two or more parts of the same piece are subjected to different temperatures.

4. It follows that when steel has been subjected to heat not absolutely uniform over the whole mass, careful annealing should be resorted to.

5. As the change of volume due to a degree of heat increases directly and rapidly with the quantity of carbon present, therefore high steel is more liable to dangerous internal strains than low steel, and great care should be exercised in the use of high steel.

6. Hot steel should always be put in a perfectly dry place of even temperature while cooling. A wet place in the floor might be sufficient to cause serious injury.

7. Never let any one fool you with the statement that his steel possesses a peculiar property which enables it to be "restored" after being "burned;" no more should you waste any money on nostrums for restoring burned steel.

We have shown how to restore "over-heated" steel.

For "burned" steel, which is oxidized steel, there is only one way of restoration, and that is through the knobbling fire or the blast furnace.

"Over-heating" and "restoring" should only be allowable for purposes of experiment. The process is one of disintegration, and is always injurious.

8. Be careful not to overdo the annealing process; if carried too far it does great harm, and it is one of the commonest modes of destruction which the steel-maker meets in his daily troubles.

It is hard to induce the average worker in steel to believe that very little annealing is necessary, and that a very little is really more efficacious than a great deal.

Mr. Kirkaldy's experiments show conclusively:—

1st. That the breaking strain of iron and steel does not (as hitherto assumed) indicate the quality. A high breaking strain may be due to hard, unyielding character, or a low one may be due to extreme softness. The contraction of area at the fracture forms an essential element in estimating the quality.

2d. Iron when fractured suddenly produces a crystalline fracture; but if gradually, a fibrous fracture. This accounts for the anomaly in the supposed change of iron from a fibrous to a crystalline character. Sudden shoulders which prevent a regular elongation of fibre cause a sudden snap.

3d. Strength of steel is reduced by being hardened in water; but both its hardness and toughness are increased by being hardened in oil. Iron heated, and suddenly cooled in water, is hardened, and the breaking strain (if gradually applied) is increased, but it is more likely to snap suddenly. It is softened and its breaking strain reduced if heated and allowed to cool gradually. Iron if brought to a white heat, is injured if it be not at the same time hammered or rolled. Case-hardening bolts weakens them.

WORKSHOP RECEIPTS.

The following useful receipts were taken in part from F. W. Bacon, on the "Indicator:"

"It is bad practice to pack the joints of steam chests, cylinder heads, etc., with rubber; in fact any joint exposed to heat, as the sulphur used in vulcanizing, disintegrates the cast iron and inevitably corrodes the bolts in time. It may be tolerated in the manhole of the boiler."

A good manilla paper is the best thing we have found for good surfaces where the joints are thin. Printers' cardboard is most excellent where the surfaces are a little uneven, and will last longer than anything

we have ever used. The cardboard is just as good after the printers have used it.

A good cement is made by taking a quantity of pure red lead, (depending on the amount of putty required), put it in an iron mortar, or on a block, or a thick plate of iron. Put a quantity of pure white lead ground in oil, knead them together until you make a thick putty, then pound it; the more you pound it the softer it will become; roll in red lead and pound again, repeat the operation, adding red lead and pounding until the mass becomes a good stiff putty, the more pounding the better. In applying to flange or joint, it is well to put a thin grummet, or fine cord around the orifice of the pipe or joint, to prevent the cement from going into the pipe; when the bolts are to be screwed up the joints should be close together.

Another, to be used when the flanges are not faced: Make the mass rather soft and add cast iron borings; pound it thoroughly until it is sufficiently soft to spread.

Both of the above are the most durable cements known to the engineer. They will resist fire and set in water.

BELT DRESSING.—A good dressing for leather belts is: One part of beef kidney tallow and two parts of castor oil well mixed and applied warm. It will be well to moisten the belt slightly with warm (not hot) water before applying it. No rats or other vermin will touch it after one application.

Value of Pea and Dust Coal, as compared with lump of good merchantable quality, with a blast induced by "Hancock's Steam Blower."

2,000 lbs. of pea and dust, the screenings from the coal yards, have been found equal to 1,600 lbs. of lump. This is a result of several weeks' trial with the same engine and boiler doing the same work.

Value of Cumberland coal as compared with anthracite. Two tons (4,000 lbs.,) of anthracite furnished steam for an engine seven days. The same amount of Cumberland served the same engine, everything else the same, eight days. This experiment was continued with alternate changes for two months.

Boiler, locomotive type, with natural draft.

This is confirmed by the author, who has found in his experience a saving of 10% to 15% in favor of Clearfield or George's Creek bituminous coal.

TO CLEAN GAUGE GLASSES.—Gauge glasses, when required to be cleaned, should have a wooden swab-stick. A metallic one will cause the tubes to fall to pieces inevitably, and sometimes immediately.

When there are indications of an extraordinary corrosion of the steam boiler and its fittings where the gauge-cocks and valves leak. Acid is suspected. Test it by putting into a sample of the water a strip of litmus paper; if acid is present the purple paper will be changed to red.

The writer has found two cases where the wells that supplied steam-boilers were poisoned by the *spent pickle* finding its way into the wells, thence to the boilers, and was detected as above. The iron (sulphate) was so abundant, when a proper quantity of tannin was put in, it formed a sufficient ink so that the report of the examination was written with it.—[F. W. Bacon.

When water scales the boiler. Lime is suspected. TEST.—Into a tumbler containing the suspected water put 8 or 10 grains of oxalic acid; if lime is present, the water will become milky, and after standing quiet awhile, the lime will be precipitated (oxalate of lime).

Should the precipitate not show itself, add a little ammonia, which is a more delicate test. If no precipitate is shown, it is not lime that forms the scale.—[F. W. B.

STRONG CEMENT for leather belts and aprons:—1¼ pints of soft water, ¾ lbs. best Frost glue, 2 oz. No. 1 white glue, 1 oz. American isinglass. Cook until it is all dissolved and fit to use, then add 2 oz. dry powdered white lead, white of egg beaten to froth; stir thoroughly, and remove from fire and allow it to cool 10 minutes, then add and stir in ½ oz. of bleached shellac cut in 4 oz. of alcohol and 1 oz. of ether.

COMMON CEMENT for leather belts:—Take of good glue and isinglass equal parts, and place in a glue pot, add water to cover the whole, soak 10 hours and bring to boiling heat, add pure tannin till the mass becomes roapy, add the whites of eggs sufficient, while warm. Buff off the leather where it is to be cemented, rub the surfaces of the joints solidly together, let it dry a few hours. and it is ready for use. If properly put together no rivets are needed as the cement is as strong as the leather.

CEMENT for leather lagging or iron pulleys:—4 parts strong glue, 1 part pitch, put on hot. Draw leather very tight with a good leverage or tackle. Clean surface of pulley with benzine.

CEMENT for holes in iron, brass, or copper kettles:—Equal parts of litharge and glycerine, made into a stiff putty. Fill the hole and round it over on each side, let it stand until hard. Water can be boiled in the kettle without leaking.

PARTING SAND.—Burnt sand scraped from the surface of castings.

LOAM.—Mixture of brick, clay and old foundry sand.

BLACKENING FOR MOULDS.—Charcoal powder; or, in some instances fine coal dust.

BLACK WASH.—Charcoal, plumbago and size.

MIXTURE FOR WELDING STEEL.—1 sal-ammoniac, 10 borax. Pounded together, and fused until clear, when it is poured out, and, after cooling, reduced to powder.

RUST-JOINT CEMENT. (Quickly setting.)—1 sal-ammoniac in powder (by weight), 2 flour of sulphur, 80 iron borings, made to a paste with water.

RUST-JOINT. (Slowly setting.)—2 sal-ammoniac, 1 flour of sulphur, 200 iron borings. The latter cement is the best if the joint is not required for immediate use.

RED LEAD CEMENT FOR FACE-JOINTS.—1 of white lead, 1 of red lead mixed with linseed oil to the proper consistency.

CASE-HARDENING.—Place horn, hoof, bone dust, or shreds of leather, together with the article to be case-hardened, in an iron box subject to a blood-red heat, then immerse the article in cold water.

CASE-HARDENING WITH PRUSSIATE OF POTASH.—Heat the article after polishing to a bright red, rub the surface over with prussiate of potash; allow it to cool to a dull red, and immerse it in water.

CASE-HARDENING MIXTURE.—3 prussiate of potash, 1 sal-ammoniac, or, 1 prussiate potash, 2 sal-ammoniac, 2 bone dust.

GLUE TO RESIST MOISTURE.—1 pound of glue melted in 2 quarts of skim-milk.

MARINE GLUE.—1 of India-rubber, 12 of mineral naphtha or coal tar. Heat gently, mix. and add 20 of powdered shellac. Pour out on a slab to cool. When used, to be heated to about 250°.

GLUE CEMENT TO RESIST MOISTURE.—1 glue, 1 black resin, ¼ red ochre. Mixed with least possible quantity of water. Or, 4 of glue, or 1 oxide of iron, 1 of boiled oil (by weight).

TO REMOVE RUST FROM STEEL.—Steel which has been rusted can be cleaned by brushing with a paste compound of ½ oz. cyanide potassium, ½ oz. castile soap, 1 oz. whiting, and water sufficient to form a paste. The steel should be washed with a solution of ½ oz. cyanide potassium in 2 oz. water.

TO PRESERVE STEEL FROM RUST.—1 caoutchouc, 16 turpentine. Dissolve with a gentle heat, then add 8 parts boiled oil. Mix by bringing them to the heat of boiling water; apply to the steel with a brush, in the way of varnish. It may be removed with turpentine.

TO CLEAN BRASS.—1 Roche alum and 16 water. Mix. The article to be cleaned must be made warm, then rubbed with the above mixture, and finished with fine tripoli.

DIFFERENT COLORS OF IRON, CAUSED BY HEAT.

Deg. Cen.	Deg. Fah.	
261 370	502 680	Violet, purple and dull blue. Between 261° C to 370° C it passes to bright blue, sea green, and then disappears.
500	932	Commences to be covered with a light coating of oxide: becomes a deal more impressible to the hammer, and can be twisted with ease.
525	977	Becomes nascent red.
700	1292	Sombre red.
800	1472	Nascent cherry.
900	1657	Cherry.
1000	1832	Bright cherry.
1100	2012	Dull orange.
1200	2192	Bright orange.
1300	2372	White.
1400	2552	Brilliant white-welding heat.
1500 1600	2732 2912	Dazzling white.

MELTING POINT OF METALS.

Platinum,	3080°	Fah.	(Pouillet)	Silver,	1832°	Fah.	(Pouillet)
Wrought iron,	2822	"	"	Antimony,	842	"	(I. L. Bell)
Steel,	2462	"	"	Zinc,	782	"	"
Cast iron (Gray)	2210	"	"	Lead,	620	"	"
Gold,	2192	"	"	Tin,	475	"	"

EXPANSION OF METALS. (Faraday.)

	At 212°	Ex. per deg. Fah.
Brass..	1.0019062	.0000106
Copper	1.001745	.0000097
Cast Iron	1.0011112	.0000062
Steel	1.0011899	.0000066
Wrought Iron	1.0012575	.000007
Tin	1.002	.0000111
Zinc	1.002942	.0000163

The length of the bar at 32°=1.

Almost all bodies expand in equal proportion for each degree between freezing and boiling.

To ascertain the expansion of a body: Multiply the dimension of the body by the number of degrees of increase of temperature and then by the expansion per degree.

EXAMPLE:—Required the expansion of a steel rail 30 feet long, with an increase of temperature of 100°:

$$30\times100=3000\times.0000066=.0198 \text{ foot}=\tfrac{1}{4} \text{ inch.}$$

DECREASE OF STRENGTH OF WROUGHT IRON AT HIGH TEMPERATURE.

(Experiments by W. Johnson and Benj. Reeves, Com. Franklin Ins., 1839.)

Temperature.		Decrease per ct. of max. tena'y.	Temperature.		Decrease per ct. of max. tena'y.
Cen.	Fah.		Cen.	Fah.	
271°	520°	.0738	500°	932°	.3324
313		.0899	554		.4478
332	630	.1047	599		.5514
350		.1155	624	1154	.6
389	732	.1491	669		.6622
440		.2010	708	1306	.7001

STRENGTH OF MANILA AND HEMP ROPES.

"The strength of rope is very irregular, much depending on the quality of the fibre used and the solidity in which the rope is put together. For instance, 3¼ inch circumference soft-laid rope will not measure over 3 inch circumference hard-laid.

"Our tests of the various makes of rope from the manila fibre, show about the following average maximum strength:

3 inch	circumference,	soft-laid,	7,300 lbs:
3 "	"	medium-laid,	8,000 "
3 "	"	hard-laid,	9,000 "

"We find it a safe rule, up to 5-inch circumference, to multiply the square of the circumference by 8 and the product will be the number of net 100 lbs. required to break the rope.

"From the tests we have from the U. S. Govt. Cordage works, of the breaking strength of tarred Russia and American hemp cordage, we would say that the above rule will apply to tarred cordage as well as to manila.

"Where blocks and falls are used it is a safe rule to put rope in use at

⅛ its breaking strain; and that in two double-blocks of suitable size. Say, for instance, it is desired to raise regularly 1000 lbs.—two double 8-inch blocks reeved with 3-inch circumference manila rope should be used.

"For direct pulls on a single rope, say up to 5-inch circumference, we find it safe where in constant use to put it at work at only 1-20 its breaking strain. For instance, on a hoisting machine in a warehouse where hoists of 1000 to 1500 lbs. are made (the latter occasionally), we place for the hook rope 5-in. cir. manila rope. This gives durability, and allows for wear and tear.

"Of course wear and tear and the want of proper care must be allowed for as rope grows old. The best rope made will be quickly destroyed by allowing it to become wet and then putting it in a damp cellar or room where there is no circulation of air."

WEIGHT AND STRENGTH OF SHORT-LINK IRON CHAINS.

Since each link consists of two thicknesses of bar, it might be supposed that a chain would possess double the strength of a single bar, but the strength of the bar becomes reduced about 3-10 by being formed into links; so that the chain really has but about 7-10 of the strength of two bars. As a thick bar of iron will not sustain as heavy a load in proportion as a thinner one, so of course, large chains are proportionately weaker than smaller ones. In the following table, 20 tons (gross) per sq. inch is assumed as the average breaking strain of a single straight bar of ordinary rolled iron 1 inch in diameter; 19 tons, from 1 to 2 in. dia.; and 18 tons from 2 to 3 in. dia. Deducting 3-10 from each of these, we have as the breaking strain of the two bars composing each link as follows: 14 tons per sq. inch, up to 1 inch diameter; 13.3 tons, from 1 to 2 in.; and 12.6 tons from 2 to 3 in. dia., and upon these assumptions the table is based.—[Trautwine.

TABLE

OF WEIGHTS AND STRENGTH OF SHORT-LINK IRON CHAINS.

Dia. of iron.	Av. wt. per ft.	Break'g. strain	Dia. of iron.	Av. wt. per ft.	Break'g. strain
Ins.	Lbs.	Lbs.	Ins.	Lbs.	Lbs.
3-16	.42	1,731	1	10.	49,280
¼	.91	3,069	1-16	11.8	52,790
5-16	1.22	4,794	⅛	12.5	59.226
⅜	1.5	6,922	3-16	14.	65,960
7-16	2.	9,408	¼	15.5	73,114
½	2.5	12.320	⅜	18.5	88,301
9-16	3.2	15,590	½	22.	105,280
⅝	4.1	19,219	⅝	25.5	123,514
11-16	5.	23,274	¾	29.5	143.293
¾	5.8	27.687	⅞	33.5	164,505
13-16	6.6	32,307	2	38.	187.152
⅞	7.7	37,632	¼	48.5	224,448
15-16	8.9	43,277	½	60.0	277,088

TO CRUSH AN INCH CUBE OF

Wrought iron, requires .... 16 tons.
Cast iron, " .... 49 "
Steel, " .... 100 "

WROUGHT IRON TIE RODS AND KING BOLTS.

Span of Roof.	Diam. of T. R.	Diam. of K. B.
20 to 25 feet	1 inch.	3/4 inch.
25 to 30 "	1 1/8 "	7/8 "
30 to 35 "	1 1/8 "	7/8 "
35 to 40 "	1 1/4 "	1 "
40 to 45 "	1 3/8 "	1 1/8 "
45 to 50 "	1 1/2 "	1 1/4 "
50 to 60 "	1 3/4 "	1 3/8 "

TO FIND THE WEIGHT OF TIMBER WORK.

Timber flooring:

RULE.—Multiply breadth in feet by length in feet by thickness in inches and by one of the following factors according to material: For elm, use 3.5 lbs.; for yellow pine, 3.42; for white pine, 2.97; for dry oak, 4.04.

To find weight of timber beams, posts and joists:

RULE:—Multiply length in feet by breadth and depth in inches, and the product by one of the following factors: For elm, 2.92; yellow pine, 2.85; white pine, 2.47; dry oak, 4.04.

Weight per 1000 (M) feet board measure:

	Dry.	Part Season.	Gr'n.
	Lbs.	Lbs.	Lbs.
Pine and Hemlock.........	2,500	2.750	3.000
Nor. and Yellow Pine....	3,000	4 000	5,000
Oak and Walnut...........	4,000	5.000	
Ash and Maple...........	3,500	4,000	

If the sap of green timber be prevented from escaping at the ends of the sticks, as in the case of girders, etc., enclosed air-tight in brick-work or masonry, its fermentation will produce dry rot. The painting of green timber conduces to the same end. Alternate exposure to water and air produces wet rot.

In a free circulation of dry air, timber will endure for centuries, if not attacked by worms.

SHINGLES.

The best shingles are of white cedar. When of good quality, they will last 40 to 50 years in our northern states. Cypress and white pine are much used for shingles, but will not last half as long as white cedar.

Shingles are packed 250 to the bundle, or 4 bundles to 1000.

1 bundle 16-inch shingles will cover 30 square feet.

1 bundle 18-inch shingles will cover 33 square feet.

When laid 5 1/2 inches to the weather, 5 lbs. 4° or 3 3/4 lbs. 3° nails will lay 1000 shingles.

CLAP-BOARDS.

1 bundle when laid 3 1/2 inches to the weather will cover 26 square feet.

PAINTING.

For outside wood-work, paint made from white lead ground in linseed

oil is most used. If the oil is raw, or unboiled, dryer is added; if boiled, no dryer is necessary. Not less than four coats should be applied—5 are better.

Paint, ready-mixed, put up in cans or kegs, may be procured from the manufacturers or dealers. These paints have to be thinned by adding 1 pint of oil to about 2½ lbs. of paint. When thinned, 1 lb. will cover about 2 square yards of first-coat, 3 yards of second, and 4 yards of each subsequent coat; or 1⅜ lbs. to the square yard will be required for 4 coats, and 1⅝ lbs. for 5 coats.

For inside work, either white lead or oxide of zinc is used, and for good work 4 coats are necessary.

For iron exposed to the weather, metallic paints, such as yellow and red iron ochers or brown hematite ore, finely pulverized and mixed with oil or dryer, are best.

For iron subject to the action of water, red lead is best.

Plastered walls should stand a year before painting.

Painting is measured by the square yard, girding every part of the work that is covered by paint and allowing an addition to the actual surface for the difficulty of covering deep quirk of mouldings and for "cutting in" as in sash and shelving, or where there is a change of color, on same work.

WASHES.

For outside wood-work: In a tight-bushel, slack half a bushel of fresh lime by pouring over it boiling water sufficient to cover it 4 or 5 inches deep, stir until slacked; add 2 lbs. of sulphate of zinc dissolved in water, add water enough to bring all to the consistency of thick whitewash.

For inside work: Add 2 quarts of thin size to a pailful of wash just before using. The common practice of mixing salt with whitewash should not be permitted.

For brick or stonework: Slack ½ bushel of lime, as before, in a barrel, then fill the barrel two-thirds full of water and add a bushel of hydraulic cement; add 3 lbs. sulphate of zinc dissolved in water.

These washes may be colored by adding powdered ochre, umber, etc.

WEIGHT OF SKYLIGHT AND FLOOR GLASS PER SQUARE FOOT.

	Thickness in Inches.							
	⅛	3-16	¼	⅜	½	⅝	¾	1
Wt.	1.75	2.62	3.5	5.35	.7	8.75	10.5	14.

PAINTER'S PUTTY.

Spanish whiting, pulverized, 80.6; boiled oil, 20.4; made into a stiff paste. If not intended for immediate use, raw linseed oil should be used.

One pound of putty for stopping every 20 yards.

GLAZIER'S PUTTY.

Whiting, 70 lbs.; boiled oil, 30 lbs.; water, 2 gals. Mix. If too thin, add more whiting; if too thick, add more oil.

TO SOFTEN PUTTY.

To remove old putty from broken windows, dip a small brush in nitromuriatic acid or caustic soda (concentrated lye), and with it annoint or paint over the dry putty that adheres to the broken glass and frames of your windows; after an hour's interval the putty will have become so soft as to be easily removable.

TABLE

SHOWING WEIGHT OF LEAD PIPE REQUIRED FOR A GIVEN HEAD (OR FALL) OF WATER.

Head or feet fall.	Pressure sq. inch.	Calibre and weight per foot.						
		$\frac{3}{8}$ inch.	$\frac{1}{2}$ inch.	$\frac{5}{8}$ inch.	$\frac{3}{4}$ inch.	1 inch.	$1\frac{1}{4}$ inch.	$1\frac{1}{2}$ inch.
feet.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
20	10	.38	.63	.87	1.	1.5	2.	3.
30	15	.5	.75	1.38	1.5	2.	2.5	3.5
40	20	.63	1.	1.75	2.	2.5	3.	4.
50	25	.75	1.25	2.	2.5	3.	4.	5.
75	38	1.	1.63	2.38	3.38	4.	5.	6.
100	50	1.25	2.	3.	4.	5.	7.	10.
150	75	1.38	2.5	3.5	4.5	6.	9.	12.
200	100	1.5	3.	4.	5.	7.	12.	15.

The above weights of pipe are of sufficient strength to permit the water to be shut off, or stopped. When the water is permitted to run constantly two-thirds of the above weight will answer.

QUANTITY OF WATER THAT WILL FLOW THROUGH A PIPE 500 FEET LONG IN 24 HOURS, WITH A FALL OF 10 FEET.

$\frac{3}{8}$ inch bore,	576 gallons.	$\frac{3}{4}$ inch bore,	3,200 gallons.
$\frac{1}{2}$ " "	1,150 "	1 " "	6,624 "
$\frac{5}{8}$ " "	2,040 "	$1\frac{1}{4}$ " "	10,000 "

Joints to lead pipes require 1 lb. of solder for every inch diameter.

LEAD PIPE.

WEIGHT PER LINEAL FOOT.

Cal. inside diam.	Thickness in Inches.							
	1-16	1-8	3-16	1-4	3-8	1-2	5-8	3-4
Ins.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
$\frac{3}{8}$	.427	.97	1.65	2.44	4.88			
$\frac{1}{2}$	.548	1.21	2.01	2.93	5.11	7.79		
$\frac{5}{8}$	.670	1.46	2.38	3.42	5.85	8.77	12.2	
$\frac{3}{4}$	.791	1.70	2.74	3.90	6.58	9.75	13.4	17.6
$\frac{7}{8}$	.911	1.95	3.11	4.39	7.31	10.7	14.6	19.1
1	1.03	2.19	3.47	4.88	8.04	11.7	15.8	20.5
$\frac{1}{4}$	1.18	2.69	4.21	5.85	9.5	13.7	18.3	23.4
$\frac{1}{2}$	1.52	3.18	4.94	6.83	11.	15.6	20.7	26.3
$\frac{3}{4}$	1.76	3.67	5.67	7.81	12.4	17.6	23.2	29.3
2	2.01	4.16	6.40	8.78	13.9	19.5	25.6	32.2
$\frac{1}{4}$	2.25	4.65	7.13	9.76	15.4	21.5	28.1	35.1
$\frac{1}{2}$	2.49	5.14	7.86	10.7	16.8	23.4	30.5	38.
$\frac{3}{4}$	2.73	5.63	8.59	11.7	18.3	25.4	32.9	41.
3	2.98	6.12	9.32	12.7	19.7	27.3	35.4	43.9
$\frac{1}{2}$	3.46	7.10	10.8	14.6	22.7	31.3	40.3	49.7
4	3.95	8.08	12.2	16.6	25.6	35.2	45.2	55.6

BRICK WORK.

Brick work is generally measured by 1000 bricks laid in the wall. In consequence of variations in size of bricks, no rule for volume of laid brick can be exact. The following scale is, however, a fair average:

EASTERN MAKE—8″ x 4″ x 2¼″.	WESTERN MAKE—8¾″x4¼″x2¾″.
8 common to a super. foot 4″ wall	7 common to a super. foot 4″ wall
16 " " " " 8″ "	14 " " " " 9″ "
24 " " " " 12″ "	21 " " " " 13″ "
32 " " " " 16″ "	28 " " " " 18″ "
40 " " " " 20″ "	35 " " " " 22″ "
Weight about 4 lbs. each.	Weight, about 5½ lbs. each.

Brick wall laid in mortar, when dry will weigh 108 lbs. to cubic feet.

Corners are not measured twice as in stone work. Openings over 2 feet square are deducted. Arches are counted from the spring. Fancy work counted 1½ bricks for 1. Pillars are measured on their face only.

A cubic yard of mortar requires 1 cubic yard of sand and 9 bushels of lime, and will fill 30 hods.

1000 bricks, closely stacked, occupy about 56 cubic feet.

1000 old bricks, cleaned and loosely stacked, uccupy about 72 cubic foot.

One superficial foot of guaged arches requires 10 bricks.

Paving bricks should measure 9 x 4½ x 1¾ inches, and weigh about 4¼ lbs.

One yard of paving when laid flat requires 40 Eastern brick, 36 Western; on edge, 72 Eastern, 54 Western; or above dimensions of paving brick, 32 when laid flat, 82 on edge.

STONE WORK.

Stone walls are measured by the perch (24¾ cubic feet). Openings less than 3 feet wide are counted solid; over 3 feet deducted, but 18 inches are added to the running measure for each jamb built. Arches are counted solid from their spring. Corners of buildings are measured twice. Pillars less than 3 feet are counted on 3 sides as lineal, multiplied by fourth side and depth.

It is customary to measure all foundation and dimension stone by the cubic foot. Water tables and base courses by lineal feet. All sills and lintels or ashlar, by superficial feet, and no wall less than 18 inches thick.

The greatest safe load per super. foot on

Granite piers.................................=40 tons.
Lime stone piers.............................=25 "
Sand stone piers............................. =15 "
Brickwork in cement.........................= 3 "
Rubble masonry..............................= 2 "
Lime concrete foundations...................= 2½ "

The height of brick or stone piers should not exceed 12 times their least thickness at base.

Allow for floors of	per sq. ft.
Dwellings..	140 lbs.
Public buildings....................................	170 "
Warehouses, etc....................................	280 "

Allow for roofs:	per sq. ft.
Corrugated iron laid directly on the purlines...........	37 lbs.
Corrugated iron laid on boards........................	40 "
Slate, nailed to laths................................	43 "
Slate, laid on boards.................................	46 "
Add for wind and snow................................	20 "
If plastered below the rafters, add.....................	10 "

TABLE.

SAFE LOAD FOR HOLLOW CAST IRON PILLARS. (Tons. 2240 lbs.)

External diameter in inches	Thickness of metal=½ inch. Length in Feet. 8	10	12	14	16
3	4.0	3.2	2 3	1.8	1.4
3½	5.9	5.1	3.6	2.7	2.3
4	8.1	6.1	4 7	3.6	3.4
4½	10.6	8.1	6.5	5.0	4.4
5	13.3	10.4	8.3	6.7	5.4
5½	15.3	12.9	10.5	8.5	7.0
6	19.0	15.5	12.7	9.5	8.7
	Thickness of metal=⅝ inch.				
3	4.7	3.5	2.6	2.0	1.6
3½	7.1	5.3	4.2	3.2	2.5
4	9.2	7.3	5.6	4.4	3.9
4½	12.8	9.9	7.7	6.1	5.5
5	16.1	12.7	9.1	8.1	7.0
5½	18.7	15.7	12.8	10.4	8.8
6	23.2	19.0	15.6	12.8	10.6
6½	26.9	22.4	18.7	15.2	13.0
7	30.7	26.0	21.9	18.5	15.6
	Thickness of metal=¾ inch.				
3	5.4	3.8	2.8	2.2	1.7
3½	8.1	6.2	4.4	3.5	2.6
4	11.3	8.5	6.5	4.8	3.8
4½	14 9	11.5	8.9	7.2	6.0
5	18.8	14.8	11.7	9.0	7.7
5½	21.8	18.4	14.9	12.1	10.2
6	27.2	22.8	18.3	15.0	12.5
6½	31.6	26.3	21.9	17.8	15.3
7	36.1	30.6	25.8	21.7	18.4
	Thickness of metal=1 inch.				
4	13.9	10.4	8.0	6.4	4.8
4½	18.5	14.3	11.1	8.8	7.1
5	23.6	18.6	14.8	11.9	9.6
5½	27.6	23.2	18.9	15.3	12.7
6	34.5	28.3	23.2	19.1	15.9
6½	40.3	33.6	28.0	22.8	19.6
7	46.2	39.1	33.0	27.8	23.6
7½	52.2	44.9	38.3	32.6	27.9
8	58.8	50.7	43.8	37.7	32.5
8½	64.3	56.5	49.4	42.9	37.3
9	70.5	62.7	55.3	48.1	42.3
Diam. in In.	STRENGTH OF CAST IRON SOLID PILLARS.				
2	1.4	1.0	.7	.50	.44
2¼	2.1	1.5	1.0	.83	.66
2½	2.9	2.1	1.6	1.21	.95
2¾	4.0	3.0	2.2	1.72	1.35
3	6.0	4.0	3.0	2.30	1.84

TABLE.

Strength of Rolled Iron Beams.

B. W.=Breaking weight distributed in tons.

Depth of beam.	Size of flange.	B. W. for different spans.			
		10 feet.	15 feet.	20 feet.	25 feet.
5	2 × ½	6.6			
6	2½ × ½	10.	6.6	5	
7	3 × ½	14.	9.	7	5
8	3 × ⅝	20.	13.	10	8
9	4 × ¾	36.	24.	18	14
10	4½ × 1	60.	40.	30	24

PLASTERING.

Estimate of Material for 100 Square Yards.

Materials.	Two coats slipped coat finish.	Three coats with hard finish.
Quicklime	3½ casks	4 casks
" for fine stuff..		⅜ "
Plaster of Paris........		½ "
Laths..................	2000	2000
Hair.....................	3 bushels	4 bushels
Common sand	6 loads	7 loads
White sand.............		2½ bushels
Nails	13 lbs.	13 lbs.
Mason's labor.	3½ days	4 days
Laborer................	2 "	3 "

Plastering laths are usually of white or yellow pine, 1½ inches wide, ¼ inch thick, and 3 or 4 feet long. They are nailed up horizontally, about ½ inch apart. The upright stud of partitions are spaced at such distances apart (usually about 15 inches, centre to centre), that the ends of the laths may be nailed to them. Laths are sold in bundles of 1000 each. A square foot of surface requires 1½ four-feet laths, or 1000 such laths will cover 666 square feet. A carpenter can nail up the laths for from 40 to 60 square yards of plastering in a day of 10 hours, depending upon the number of angles in the room, etc.

Plastering is always measured by the square yard for plain work, by the superficial foot for cornices of plain members, and by lineal foot for enriched or carved mouldings in cornices.

SHEET TIN.

A box of 225 sheets 13¾ ×10 contains 214.84 sq. ft.; but, allowing for seams, it will cover but 150 sq. ft. of roof.

A roof covered with tin or other metal should slope not less than 1 inch to a foot.

Leaded tin is much used for roofing. It is simply sheet iron coated with lead instead of tin, and is not as durable as the tinned sheets.

TABLE.

Sizes and Weight of Sheet Tin.

Mark.	No. of sheets in box.	Dimensions. Length. In.	Dimensions. Br'dth. In.	Weight of box in pounds.
IC	225	13¾	10	112
IIC	"	13¼	9¾	105
IIIC	"	12¾	9½	98
IX	"	13¾	10	140
IXX	"	"	"	161
IXXX	"	"	"	182
IXXXX	"	"	"	203
DC	100	16¾	12½	105
DX	"	"	"	126
DXX	"	"	"	147
DXXX	"	"	"	168
DXXXX	"	"	"	189
5 DC	200	15	11	168
5 DX	"	"	"	189
5 DXX	"	"	"	210
5 DXXX	"	"	"	231
5 DXXXX	"	"	"	252
ICW	225	13¾	10	112

Where coal is used for fuel, tin roofs should receive a good coat of paint when first put on, and a coat every year after. Spanish brown is an excellent paint for this purpose.

SLATING.

A square of slate or slating is 100 superficial feet.

In measuring, the width of the eaves is allowed at the widest part. Hips, valleys and cutting are to be measured lineal, and 6 inches width extra is allowed.

The thickness of slates ranges from 3-16 to 5-16 of an inch, and their weight varies from 2.6 to 4.5 lbs. per square foot.

The lap of slates varies from 2 to 4 inches. The standard is assumed to be 3 inches.

Dimensions of Slates and Number Required to a Square.

AMERICAN.

Size.	No. of slate.	Weight per sq. about	Size.	No. of slate.	Weight per sq. about
12×6	533	lbs.	18×11	174	lbs.
12×7	457	850	20×10	169	
12×8	400		20×11	154	650
14×7	374		20×12	141	
14×8	327	750	22×11	138	
14×9	291		22×12	126	
16×8	277		22×13	116	
16×9	246		24×12	114	675
16×10	221	650	24×13	105	
18×9	213		24×14	98	
18×10	192				

To compute the number of slates of a given size required per squares: Subtract 3 inches from the length of the slate, multiply the remainder by the width and divide by 2. Divide 14,400 by the number so found, and the result will be the number of slates required.

The pitch of a slate roof should not be less than 1 inch height to 4 inch length.

Good American slate weighs about 174 lbs. per cubic foot. Hence

Slabs	¾″	thick	weigh	10.86	pounds	per	square	foot.
"	1″	"	"	14.5	"	"	"	"
"	1¼″	"	"	18.12	"	"	"	"
"	1½″	"	"	21.72	"	"	"	"
"	2″	"	"	29.	"	"	"	"

CORRUGATED IRON ROOFING.

B. W. Gauge.	Wt. per square (100 sq. ft.) Plain or paint.	Galvanized.
No. 28	97 lbs.	Galvanized iron weighs from 5 to 15 per cent. heavier than plain, according to the No. B. W. G.
" 26	105 "	
" 24	128 "	
" 22	150 "	
" 20	185 "	
" 18	270 "	
" 16	340 "	

For a good durable roof, lighter than No. 22 is not recommended.

Corrugated iron is usually made in sheets from 6 to 8 feet long, and from 2 to 3 feet wide.

The sheets when used for roofing, should overlap about 6 inches in girth, and be double riveted at the joints.

One-third of the net width may be allowed approximately for lappage and corrugations.

From 2½ to 3½ lbs. of rivets will be required for a square.

DECIMAL EQUIVALENTS OF INCHES, FEET AND YARDS.

Frac. of an inch.		Dec. of an inch.		Dec. of a foot.
1-16	=	.0625	=	.00521
⅛	=	.125	=	.01041
3-16	=	.1875	=	.01562
¼	=	.25	=	.02083
5-16	=	.3125	=	.02604
⅜	=	.375	=	.03125
7-16	=	.4375	=	.03645
½	=	.5	=	.04166
9-16	=	.5625	=	.04688
⅝	=	.625	=	.05208
11-16	=	.6875	=	.05729
¾	=	.75	=	.06250
13-16	=	.8125	=	.06771
⅞	=	.875	=	.07291

Ins.		Feet.		Yards.
1	=	.0833	=	.0277
2	=	.1666	=	.0555
3	=	.25	=	.0833
4	=	.3333	=	.1111
5	=	.4166	=	.3389
6	=	.5	=	.1666
7	=	.5833	=	.1944
8	=	.666	=	.2222
9	=	.75	=	.25
10	=	.8333	=	.2778
11	=	.9166	=	.3055
12	=	1.	=	.3333

Decimal Equivalents of Ounces and Pounds.

Oz.		Lbs.	Oz.		Lbs.	Oz.		Lbs.
¼	=	.015625	4	=	.25	8½	=	.5343
½	=	.03125	4½	=	.2813	9	=	.5625
¾	=	.046875	5	=	.3125	10	=	.625
1	=	.0625	5½	=	.3438	11	=	.6875
1½	=	.09375	6	=	.375	12	=	.75
2	=	.125	6½	=	.4063	13	=	.8125
2½	=	.15625	7	=	.4375	14	=	.875
3	=	.1875	7½	=	.4688	15	=	.9375
3½	=	.21875	8	=	.5	16	=	1.

USEFUL NUMBERS.

Lineal feet,	× .00019	=	miles.
" yards,	× .0006	=	"
Square inches,	× .007	=	square feet.
" feet,	× .111	=	" yards.
" yards,	× .0002067	=	acres.
Acres,	× 4840	=	square yards.
Cubic inches,	× .00058	=	cubic feet.
" feet,	× .03704	=	" yards.
Circular inches,	× .00546	=	square feet.
Cylindrical inches,	× .0004546	=	cubic feet.
" feet,	× .02909	=	" yards.
Links,	× .22	=	yards.
"	× .66	=	feet.
Feet,	× 1.5	=	links.
Width in chains,	× 8.	=	acres per mile.
183,346 circular inches,		=	1 square foot.
2200 cylindrical inches,		=	1 cubic foot.
Cubic feet,	× 7.48	=	U. S. gallons.
" inches,	× .004329	=	" "
Cylindrical feet,	× 5.874	=	" "
" inches,	× .0034	=	" "
U. S. gallons,	× .13367	=	cubic feet.
" "	× 231.	=	" inches.
Cubic feet,	× .8036	=	U. S. bushel.
" inches,	× .000466	=	" "
U. S. bushels,	× .0495	=	cubic yards.
" "	× 1.2446	=	" feet.
" "	× 2150.42	=	" inches.
Cylindrical feet of water,	× 6.	=	U. S. gallons.
Pounds avoirdupois,	× .009	=	cwt. (112.)
" "	× .00045	=	tons (2240).
Cubic feet of water,	× 62.5	=	lbs. avoirdupois.
" ins. "	× .03617	=	" "
Cylindrical feet of water,	× 49.1	=	" "
" ins. "	× .02842	=	" "
13.44 U. S. gallons of water,		=	1 cwt.
268.8 " " "		=	1 ton.
1.8 cubic feet of water,		=	1 cwt.
35.88 " " "		=	1 ton.
Column of water 12 ins. high, 1 inch diameter,		=	.341 lbs.

CIRCUMFERENCE, AREAS, SQUARES, ETC., OF CIRCLES.

Advancing by 16ths, 8ths. and 4ths.—1 to 9¾.

Dia. or No.	Circum.	Area.	Square.	Cube.	Sq. Root.	Cube root.
1	3.14	.7854	1.	1.	1.	1.
1-16	3.34	.886	1.13	1.19	1.031	1.020
1/8	3.53	.994	1.27	1.49	1.060	1·040
3-16	3.73	1.107	1.41	1.67	1.089	1.059
1/4	3.93	1.227	1.56	1.95	1.118	1.077
5-16	4.12	1.353	1.72	2.26	1.146	1.095
3/8	4.32	1.485	1.89	2.60	1.173	1.112
7-16	4.52	1.623	2.07	2.97	1.199	1.129
1/2	4.71	1.767	2.25	3 38	1.225	1.145
9-16	4.91	1.917	2.44	3.82	1.250	1.161
5/8	5.11	2 074	2 64	4.29	1.275	1.176
11-16	5.30	2.236	2.85	4.80	1.299	1.191
3/4	5.50	2.405	3.06	5.36	1.323	1.205
13-16	5.69	2.580	3.29	5.95	1.346	1.219
7/8	5.89	2.761	3.52	6.59	1.369	1.233
15-16	6.09	2.948	3.75	7.27	1.392	1.247
2	6.28	3.142	4.	8.	1.414	1.260
1-16	6.48	3.341	4.25	8.77	1.436	1 273
1/8	6.68	3.547	4.52	9.59	1.458	1.286
3-16	6.87	3.758	4.78	10.47	1.479	1.298
1/4	7.07	3.976	5.03	11.39	1.5	1.310
5-16	7.26	4.200	5.35	12.36	1.521	1.322
3/8	7.46	4.430	5.64	13.40	1.541	1.334
7-16	7.66	4.666	5.94	14.48	1.561	1.346
1/2	7.85	4.900	6.25	15.63	1.581	1.358
9-16	8.05	5.157	6.57	16.83	1.600	1.369
5/8	8.25	5.412	6.89	18.08	1.620	1.380
11-16	8.44	5.673	7.22	19.41	1.639	1.391
3/4	8.64	5.940	7.56	20.79	1.658	1.402
13-16	8.84	6.213	7.91	22.25	1.677	1.412
7/8	9.03	6.492	8.27	23.76	1.695	1.422
15-16	9.23	6.777	8.63	25.34	1.714	1.432
3	9.42	7.07	9.	27.	1.732	1.442
1/8	9.82	7.67	9.77	30.52	1.768	1.462
1/4	10.21	8.30	10.56	34.32	1.803	1.482
3/8	10.60	8.95	11.39	38.44	1.837	1.5
1/2	11.00	9.62	12.25	42.88	1.871	1.518
5/8	11.39	10.32	13.14	47.63	1.904	1.535
3/4	11.78	11.05	14.06	52.73	1.936	1.553
7/8	12.17	11.79	15.02	58.17	1.968	1.570
4	12.57	12.57	16.	64.	2.	1.587
1/4	13.35	14.19	18.06	76.78	2 061	1.619
1/2	14.14	15.90	20.25	91.13	2.121	1.651
3/4	14.92	17.72	22.56	107.16	2.179	1.681
5	15 71	19.63	25.	125.	2.236	1.710
1/4	16.49	21.64	27.56	144.70	2.291	1.738
1/2	17.28	23.76	30.25	166.37	2.345	1.765
3/4	18.06	25.97	33.06	190.11	2.398	1.792

CIRCUMFERENCES, ETC. Continued.
Advancing by 16ths, 8ths, 4ths.—1 to 9¾.

Dia. or No.	Circum.	Area.	Square.	Cube.	Square root.	Cube root.
6	18.85	28.29	36.	216.	2.449	1.817
¼	19.64	30.68	39.06	244.14	2.5	1.832
½	20.42	33.18	42.25	274.63	2.550	1.866
¾	21.21	35.78	45.56	307.55	2.599	1.890
7	21.99	38.48	49.	343.	2.646	1.913
¼	22.78	41.28	52.56	381.08	2.692	1.935
½	23.56	44.18	56.25	421.88	2.739	1.957
¾	24.35	47.17	60.06	465.48	2.784	1.979
8	25.13	50.26	64.	512.	2.828	2.
¼	25.92	53.46	68.06	561.52	2.872	2.021
½	26.70	56.75	72.25	614.12	2.915	2.041
¾	27.49	60.13	76.56	669.92	2.958	2.061
9	28.27	63.62	81.	729.	3.	2.080
¼	29.06	67.20	85.56	791.45	3.041	2.098
½	29.85	70.88	90.25	857.37	3.082	2.118
¾	30.63	74.66	95.06	926.86	3.122	2.136

CIRCUMFERENCES, AREAS, SQUARES, CUBES, SQUARE AND CUBE ROOTS.—10 to 85.

NOTE. To find the fourth power (or biquadrate) of a number, multiply the square by the square.
To find the 4th root, extract the square root in succession.

Dia. or No.	Circum.	Area.	Square.	Cube.	Square root.	Cube root.
10	31.41	78.54	100	1000	3.162	2.154
11	34.55	95.03	121	1331	3.317	2.224
12	37.69	113.0	144	1728	3.464	2.289
13	40.84	132.7	169	2197	3.606	2.351
14	43.98	153.9	196	2744	3.742	2.410
15	47.12	176.7	225	3375	3.873	2.466
16	50.26	201.0	256	4096	4.	2.520
17	53.40	226.9	289	4913	4.123	2.571
18	56.54	254.4	324	5832	4.243	2.621
19	59.69	283.5	361	6859	4.359	2.668
20	62.83	314.1	400	8000	4.472	2.714
21	65.97	346.3	441	9261	4.583	2.759
22	69.11	380.1	484	10648	4.690	2.802
23	72.25	415.4	529	12167	4.796	2.844
24	75.39	452.3	576	13824	4.899	2.885
25	78.54	490.8	625	15625	5.	2.924
26	81.68	530.9	676	17576	5.099	2.963
27	84.82	572.5	729	19683	5.196	3.
28	87.96	615.7	784	21952	5.292	3.037
29	91.10	660.5	841	24389	5.385	3.072
30	94.24	706.8	900	27000	5.477	3.107
31	97.39	754.8	961	29791	5.568	3.141
32	100.5	804.2	1024	32768	5.657	3.175
33	103.7	855.3	1089	35937	5.745	3.208

CIRCUMFERENCES, AREAS, ETC. 10 to 85.—Continued.

Dia. or No.	Circum.	Area.	Square.	Cube.	Square root.	Cube root.
34	106.8	907.9	1156	39304	5.831	3.240
35	110.	962.1	1225	42875	5.916	3.271
36	113.1	1017.9	1296	46656	6.	3.302
37	116 2	1075.2	1369	50653	6.083	3.332
38	119.4	1134.1	1444	54872	6.164	3.362
39	122.5	1194.6	1521	59319	6.245	3.391
40	125.7	1256.6	1600	64000	6.325	3.420
41	128.8	1320.3	1681	68921	6.403	3.448
42	131.9	1385.4	1764	74088	9.481	3.476
43	135.1	1452.2	1849	79507	6.557	3.503
44	138.2	1520.5	1936	85184	6.633	3.530
45	141.4	1590.4	2025	91125	6.708	3.557
46	144.5	1661.9	2116	97336	6.782	3.583
47	147.7	1734.9	2209	103823	6.856	3.609
48	150.8	1800.6	2304	110592	6.928	3.634
49	153.9	1885.7	2401	117649	7.	3.659
50	157.1	1963.5	2500	125000	7.071	3.684
51	160.2	2042.8	2601	132651	7.141	3.708
52	163.4	2123.7	2704	140608	7.211	3.733
53	166.5	2206.2	2899	148877	7.280	3.756
54	169.6	2290.2	2916	157464	7.348	3.780
55	172.8	2375.8	3025	166375	7.416	3.803
56	175.9	2463.0	3136	175616	7.483	3.826
57	179.1	2551.8	3249	185193	7.550	3.849
58	182.2	2642.1	3364	195112	7.616	3.871
59	185.4	2734.0	3481	205379	7.681	3.893
60	188.5	2827.4	3600	216000	7.746	3.915
61	191.6	2922.5	3721	226981	7.810	3.937
62	194.8	3019.1	3844	238328	8.874	3.958
63	197.9	3117.3	3960	250047	7.937	3.979
64	201.1	3217.0	4096	262144	8.	4.
65	204.2	3318.3	4225	274625	8.062	4.021
66	207.3	3421.2	4356	287496	8.124	4.041
67	210.5	3525.7	4489	300763	8.185	4.061
68	213.6	3631.7	4624	314432	8.246	4.082
69	216.8	3739.3	4761	328509	8.307	4.102
70	219.9	3848.5	4900	343000	8.367	4.121
71	223.1	3959.2	5041	357911	8.426	4.141
72	226.2	4071.5	5184	373248	8.485	4.160
73	229.3	4185.4	5329	389017	8.544	4.179
74	232.5	4300.8	5476	405224	8.602	4.198
75	235.6	4417.9	5625	421875	8.660	4.217
76	238.8	4536.5	5776	438976	8.718	4.236
77	241.9	4656.6	5929	465533	8.775	4.254
78	245.0	4778.4	6084	474552	8.832	4.273
79	248.2	4901.7	6241	493039	8.888	4.291
80	251.3	5026.6	6400	512000	8.944	4.309
81	254.5	5153.0	6561	531441	9.	4.327
82	257.6	5281.0	6724	551368	9.056	4.345
83	260.8	5410.6	6889	571787	9.110	4.362
84	263.9	5541.8	7056	592704	9.165	4.379
85	267.0	5674.5	7225	614125	9.220	4.397

REGULAR POLYGONS.

Area of any regular polygon=radius of inscribed circle×number of sides×length of one side.

No. of sides.	Name.	Area when diameter of inscribed circle=1.	Area when side=1.	Length of side when perpendicular=1.	Perpendicular when side=1.	Radius of circumscribed circle when side=1.	Len'h of side when radius of circums'd circle=1.
3	Triangle.........	1.299	0.433	3.464	0.2[illegible]9	.577	1.782
4	Square	1.000	1.000	2.000	0.500	.707	1.414
5	Pentag	.908	1.720	1.453	0.688	.851	1.176
6	Hexag...........	.866	2.598	1.155	0.866	1.000	1.000
7	Heptag	.843	3 634	.963	1.009	1.152	.868
8	Octag............	.828	4 828	.828	1 207	1.307	.765
9	Nonag	.819	6.182	.728	1.374	1.462	.684
10	Decag.......	.812	7.694	.650	1.539	1.618	.618
11	Undecag.	.807	9.366	.587	1.703	1.775	.563
12	Dodecag.........	.804	10.196	.536	1.866	1.932	.518

MENSURATION.

Area of a triangle=base×½ altitude.

Area of a parallelogram=base×altitude.

Area of a trapezoid=altitude×½ the sum of parallel sides.

Area of a trapezium; divide into two triangles and find area of the triangles.

Circumference of circle=diameter×3.1416.

Diameter of circle=circumference×.3183.

Area of circle=diameter²×.7854.

Area of sector of circle=length of arc×½ the radius.

Area of segment of circle=area of sector of equal radius.—area of triangle, when the segment is less, and+area of triangle, when the segment is greater than the semi-circle.

Area of circular ring=diameters of the two circles×difference of diameter and that product by .7854.

Side of square that shall equal area of circle=diameter×.8862, or circumference×.2821.

Diameter of circle that shall contain area of a given square=side of square×1.1284.

Area of an ellipse=product of the two diameters×.7854.

Area of a parabola=base×⅔ altitude.

Area of regular polygon=sum of its sides×perpendicular from its centre to one of its sides÷2.

Surface of cylinder or prism=area of both ends+length×circumference.

Contents of cylinder or prism=area of end×length.

Surface of sphere=diameter×circumference.

Contents of sphere=diameter³×.5236.

Convex surface of segment of sphere=height of segment×circumference of the sphere of which it is a part.

Contents of segment of sphere=(height 2+three times the square of radius of base)×(height×.5236).

Surface of pyramid or cone=circumference of base×½ of the slant height+area of the base.

Contents of pyramid or cone=area of base×⅓ altitude.

Surface of frustum of cone or pyramid=sum of circumference at both ends×½ slant height+area of both ends.

Contents of frustum of cone or pyramid=multiply areas of two ends together and extract square root. Add to this root the two areas and ×⅓ altitude.

Contents of a wedge=area of base×½ altitude.

STRENGTH AND TENSION OF IRON.

The breaking strength of good American iron is usually taken at 50,000 lbs. per square inch, with an elongation of 15 per cent. before breaking. It should not set under a strain of less than 25,000 lbs. The proof strain is 20,000 lbs. per square inch and beyond this amount iron should never be strained in practice.

MISCELLANEOUS WEIGHTS.

Barrel flour weighs	196 lbs.
" salt "	280 "
" beef "	200 "
" pork "	200 "
" fish "	200 "
Keg powder	= 25 "
Stone of lead or iron	= 14 "
Pig " "	=21½ stone.

Anthracite coal, broken, cubic foot averages 54 lbs.
A ton, loose, occupies 40 to 43 cubic feet.
Bituminous coal, broken, cubic ft. averages 49 lbs.
A ton, loose, occupies, 43 to 48 cubic feet.

Cement, (Hy.) Rosendale, bushel	=70 lbs.
" " Louisville, "	=62 "
" " Portland, "	=96 "
Gypsum, ground	=70 "
Lime, loose	=70 "
" well shaken	=80 "
Sand at 98 lbs. per cubic feet	=122½ "
18.29 bushels=ton. 1.181 ton	=cu. yd.

A cable's length	=240 yards.
20 articles	=1 score.
12 dozen	=1 gross.
12 gross	=1 great gross.
A cord of wood	=128 cubic ft.
1 hand	=4 inches.
1 span	=9 inches.

SHOEMAKER'S MEASURE.

No. 1 of small size is 4⅛ inches long.
No. 1 of large size is 8 11-24 inches long.
Each succeeding number of either size is one-third of an inch additional length.
60 pairs of shoes=1 case.

STRENGTH OF ICE.

A thickness of 2 inches will allow the passage of men in single file on a line of planks placed on the ice. No other row of planks should be placed nearer than 6 feet.

A thickness of 5 inches will allow the passage of cavalry, carts or light guns, with moderate interval between each.

A thickness of 6 inches will allow the passage of wagons drawn by horses, etc.

A thickness of 10 to 12 inches will support the heaviest load ever likely to pass over it.

MISCELLANEOUS TABLES.

CORN AND HOGS.

A bushel of corn will make 10½ lbs. of pork, gross. Then:

When corn costs	Pork costs
12¾ cents per bushel,	1¼ cents per pound.
17 " " "	2 " " "
25 " " "	3 " " "
35 " " "	4 " " "
42 " " "	5 " " "
50 " " "	6 " " "

NUMBER OF TREES ON AN ACRE.

4 feet apart	2720	15 feet apart	200
5 " "	1749	18 " "	135
6 " "	1200	20 " "	110
8 " "	689	22 " "	70
10 " "	430	30 " "	50
12 " "	325		

AREAS OF COAL FIELDS OF THE WORLD.

United States	200.000 square miles.
Europe	34.000 " "
Great Britain	6.195 " "
British America	2.200 " "

SQUARE BOX MEASURE.

A box 24 by 16 inches square, and 28 inches deep, will contain a barrel (5 bushels shelled corn).

A box 24 by 16 inches square, and 14 inches deep, will contain half a barrel.

A box 26 by 16 inches square, and 6½ inches deep, will contain one bushel.

A box 12 by 12 inches square, and 8 inches deep, will contain half a bushel.

A box 8 by 8½ inches square, and 8 inches deep, will contain a peck.

A box 8 by 8 inches square, and 4½ inches deep, will contain 1 gallon.

A box 7 by 8 inches square, and 4⅝ inches deep, will contain half a gallon.

A box 4 by 4 inches square, and 4½ inches deep, will contain 1 quart.

TREATMENT OF ACCIDENTS, ETC.

To Restore Persons Affected by Cold.

For frost-bite or numbness.—Restore warmth *gradually*, in proportion as circulation in the body or parts increases.

For a frozen limb.—Rub with snow and place in cold water for a short time. When the sensation returns, place again in cold water; add heat *very gradually*, by adding warm water.

If apparently dead or insensible.—Strip entirely of clothes, and cover body, with exception of mouth and nostrils, with *snow* or *ice-cold water*. When the body is thawed, dry it, place it in a *cold* bed; rub with warm hands under the cover; continue this for hours. If life appears, give small injections of camphor and water; put a drop of spirits of camphor on tongue, then rub the body with spirits and water—finally with spirits; then give tea, coffee, or brandy and water.

Send for a physician in all cases.

For Burns or Scalds.

In the early stage, soon after the accident, if there is no separation of the skin, *allow the bladder of water*, of whatever size, to *remain untouched;* merely dress it with a piece of linen or muslin, lightly coated with Simple Cerate.

If the skin comes off, dress the part with cotton, the object is to exclude the air and prevent suppuration. If cotton cannot be procured, apply any covering until you can have an ointment made of beeswax and sweet oil, equal parts—or lime water and linseed oil; or lay on scraped potatoes or carrots, or sprinkle flour on the injured surface when the above cannot be procured. Flour is troublesome to remove.

If the scald is extensive and on the body, *cold applications are not proper*; then use warm fomentations, or, in the case of a child, the warm bath. Keep the air from the wound as much as possible; do not remove the dressing often. When a cold lotion is used, pour it upon the rags, letting them remain undisturbed.

In Cases of Poisoning.

Send for a physician immediately.

In all cases of poisoning, the first step is to evacuate the stomach. This should be effected by an emetic which is quickly obtained, and most powerful and speedy in its operation; such is, powdered mustard (a large teaspoonful in a tumblerful of water), or salt, or ½ teaspoonful powdered ipecac every 10 to 15 minutes. When vomiting has already taken place, copious draughts of warm water or warm mucilaginous drinks should be given to keep up the effect till the poisonous substance has been thoroughly evacuated.

If vomiting cannot be produced the stomach pump must be used.

Poisons. ANTIDOTES.

Acids. The alkalies: common soap in solution is a good remedy. For *nitric* and *oxalic* acids, chalk and water are the best.

Alkalies. The vegetable acids: common vinegar is most used. Oil, as castor or olive, should be given in *large quantities.*

Iodine. Iodide of Potassium. Starch, wheat flour, in large quantities, well mixed with water. Drink freely; afterward strong mixture of vinegar and water.

Arsenic. Any oil or fat. Magnesia in large quantities.

Bismuth, Verdigris, Corrosive Sublimate. White of eggs; milk freely used, or wheat flour mixed with water; followed by an emetic.

Phosphorus. Magnesia with water and copious draughts of mucilaginous drinks.

Opium, Laudanum. Use most active emetics, mustard, etc. Keep patient in motion. Dash cold water on head and shoulders.

APPARENT DEATH FROM BREATHING NOXIOUS VAPORS, AS IN WELLS, ETC.

Send for a Physician.

If insensible, expose person to open air; sprinkle cold water on face and head; rub strong vinegar about nostrils; give drink of vinegar and water.

If suffocated by breathing fumes of charcoal, proceed as above, and excite breathing as in rules given in case of drowning.

To purify wells, etc., shower water down them until a candle will burn at the bottom with a clear flame.

SUN-STROKE.

Take patient immediately into the shade; place in a half-recumbent position—head raised; loosen cloths about neck and chest; apply immediately ice, or cold wet cloths to the head and nape of the neck, changing them frequently.

SPRAINS.

Elevate the limb; keep the joint perfectly quiet; apply lukewarm lotions or fomentations. When inflammation has ceased, apply stimulating liniments and bandages; shower the parts with cold and warm water alternately.

MARSHALL HALL'S RULES FOR THE RESUSCITATION OF PERSONS APPARENTLY DROWNED.

1. Treat the patient instantly, on the spot, in the open air, freely exposing the face, neck and chest to the breeze, except in very severe weather.
2. Send with all speed for medical aid and for articles of clothing, blankets, etc.

I. To clear the Throat.—3. Place the patient gently on the face, with one wrist under the forehead. All fluids and the tongue itself then fall forward, and leave the entrance into the windpipe free.

II. To excite Respiration.—4. Turn the patient slightly on his side; apply snuff or other irritant to the nostrils, and dash cold water on the face, previously rubbed briskly until it is warm. If there be no success lose no time, but apply the third rule.

III. To imitate Respiration.—5. Replace the patient on his face. 6. Turn the body gently but completely on the side, and a little beyond, and then on the face, alternately, repeating the measures deliberately, efficiently and preservingly, 15 times in the minute only. This number of thoracic movements per minute acts with the natural order of respiratory thoracic dilations and contractions, corresponding with a slow movement of the heart, averaging something less than 60 pulsations per minute, and therefore merits due attention. The rationale of the operations is thus: When the patient reposes on the thorax, this cavity is compressed by the weight of the body, and expiration is promoted; when he is turned on the side this pressure is removed, and inspiration is facilitated. 7. When the prone

position is resumed make equable but efficient pressure along the spine, removing it immediately before the rotation on the side. (The first measure augments expiration, the second commences inspiration.)

IV. To induce Circulation and Warmth.—8. Continuing these measures, rub the limbs upwards with a firm pressure and with energy, using handkerchiefs, etc. 9. Replace the patient's wet clothing by such other covering as can be instantly procured, each bystander supplying a coat or waistcoat. Meanwhile, and from time to time, proceed to the fifth rule.

V. To excite Inspiration.—10. Let the surface of the body be slapped briskly with the hand; or, 11. Let cold water be dashed briskly on the surface, previously rubbed dry and warm.

GEOMETRY.—Definitions.

A *Point* has position, but not magnitude.

A *Line* is length without breadth, and is either *Right*, *Curved* or *Mixed*. When no particular line is specified, a right line is meant.

A *Right Line* is a straight line, or the shortest distance between two points.

A *Mixed Line* is a right line and curved line united.

Lines are *parellel*, *oblique*, *perpendicular*, or *tangentical*, one to another.

An *Area*, *surface*, *superfices*, is the space contained within the outline or perimeter of a figure; it has no thickness, and is estimated in the *square* of some unit of measure, as square *inch*, square *yard*, etc.

A *Solid* has length, breadth and thickness, and its contents are estimated in the *cube* of some unit of measure.

An *Angle* is the diverging of two lines from each other, and is *right*, *acute*, or *obtuse*.

A *Right Angle* has one line perpendicular to another and resting upon it.

A *Triangle*, or *trigon*, is a figure having three sides.

An *Equilateral Triangle* has all its sides equal.

An *Isosceles Triangle* has two of its sides equal.

A *Scalene Triangle* has no two sides equal.

A *Right-angled Triangle* has one right angle.

An *Obtuse-angled Triangle* has one obtuse angle.

An *Acute-angled Triangle* has all its angles acute.

A *Quadrangle*, *tetragon*, *quadrilateral*, is a figure having four sides.

A *Parallelogram* is a quadrilateral figure whose opposite sides are parallel and equal.

A *Rectangle* is a parallelogram whose opposite sides are equal, its angles right angles, and its length greater than its breadth.

A *Square* is an equilateral rectangle, having all its sides equal.

A *Rhomboid* is a quadrilateral, having its opposite sides equal and parallel, its angles oblique, and a length greater than its breadth.

A *Rhombus*, or *lozenge*, is an equilateral four-sided figure, having oblique angles.

A *Trapezium* is a quadrilateral having no two sides parallel.

A *Trapezoid* is any four-sided figure having two of its sides parallel, but of unequal length.

A *Diagonal* is a line joining any two opposite angles of a figure having four or more sides.

A *Polygon* is a plain figure having more than four sides.

A *Regular Polygon* has all its sides equal.

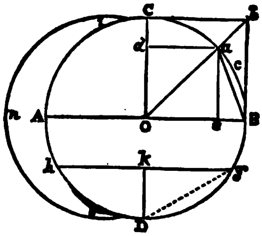
An *Irregular Polygon* has not all its sides equal.

A *Pentagon* has five sides; a *hexagon*, six; a *heptagon*, seven; an *octagon*, eight; a *nonagon*, nine; a *decagon*, ten; an *undecagon*, eleven; a *dodecagon*, twelve.

A *Perimeter* of a figure is its bounds, limits, or outline. It is to other figures what the *circumference* is to the circle, and the perimeter of any portion of a figure is the outline of that portion.

The *Altitude*, or height, of a figure, is a perpendicular let fall from its *vertex*, or highest point, to the opposite side or end, its *base*.

The *Base* of a triangle is that side that is placed parallel to the horizon; and of figures in general the base is that end, or side, upon which the figure is supposed to stand or rest. The sides of a triangle are often called the *legs*. In a right-angled triangle, the longest side, or line which subtends the right angle, is called the *hypothenuse*, and of the other two sides, one is the base, and the other the perpendicular.



A circle is a plane figure, bounded by a curve line, called the *circumference*, or *periphery*, every part of which is equi-distant from a point within called the *centre*, as A B C D, in the diagram. The circumference itself is often called a circle.

The *Radius—semi-diameter*—is a line drawn from the centre to the circumference, as O A, or O C.

The *Diameter* is a line drawn from the circumference through the centre to the opposite side, as A B.

A *Semicircle* is half a circle, or it is half the circumference of a circle, as A C B.

A *Quadrant* is a quarter of a circle. It is also sometimes a quarter of the circumference, as A C.

An *Arc* is any portion of the circumference, as B *c a*, or *h* D *g*.

A *Chord*, or *subtense*, is a right line joining the extremities of an arc, as B *a*, or *h g*.

A *Segment* is the portion of a circle contained between the arc and its chord, as the space between the arc *h* D *g* and its cord *h g*,—it is the top part of a figure, cut by a plane parallel to its base.

A *Sector* is the space between two radii, or lines passing from the centre to the circumference, as the space B O *a*.

A *Secant* is a line that cuts another line. In trigonometry, the secant of an arc is a right line drawn from the centre of a circle through one end of the arc, and terminated by a tangent drawn through the other end; thus the secant of the arc B *c a* is the line O *b*.

A *Cosecant* is the secant of the complement of an arc, as O *b*.

A *Sine* of an arc is a line drawn from one end of the arc perpendicular to a radius drawn through the other end, as *a e*, and is always equal to half the chord of double the arc; and the sine of an angle is the sine of the arc that measures that angle.

The *Versed Sine* is that portion or part of the radius lying between the sine and the end of the arc or angle, as *e* B, and the *versed sine of half the arc* is that portion of the radius lying between the chord and the arc, bisecting or dividing both at their centres, as *k* D, in the arc *h* D *g*. It is the height of the arc, or segment.

The *Cosine* of an arc, or angle, is that portion of the radius lying between the sine and the centre, as *e* O.

The *Coversed Sine* is the sine of the complement of an arc, or angle, or the coversed sine of the given arc, or angle; thus, the line *a d* is the coversed sine of the arc B *c a*, or of the angle B O.

A *Tangent* is a right line that touches a curve, and which, if produced, will not cut it—the tangent of the arc B *c a*, is B *b*.

A *Cotangent* is the tangent of the complement of an arc, or the tangent of an arc which is the complement of another arc to ninety degrees; thus, the cotangent to the arc B *c a*, is the line C *b*.

The *Complement* is what remains of the quadrant of a circle, after the angle has been taken therefrom—the complement of the arc B *c a*, is *a* O C.

The *Supplement* is what remains of a semi-circle after taking an angle therefrom—the supplement of the arc B *c a*, is *a* O A.

A *Gnomon* is the space included between two similar parallelograms, one inscribed within the other, and having one angle common to them both, as the space C *b* B *e a d* C.

A *Zone* is the space between two parallel chords of a circle—the space included between the lines A B and *h g*.

A *Lune*, or *Crescent*, is the space contained between the intersecting arcs of two *eccentric* circles, as *i n s*.

A *Circular Ring* is the space between the circumferences of two *concentric* circles.

A *Prism* is a solid whose bases or ends are any similar, equal plane figures, and whose sides are parallelograms.

A *Parallelopiped* is a solid having six sides, its angles right angles, and its opposite sides equal. It is a prism, therefore, whose base is a parallelogram.

A *Cube* is a solid having six equal sides and all its angles right angles. It is a square prism.

A *Prismoid* is a solid whose bases are parallel but unequal, and whose sides are quadrilateral.

A *Pyramid* is a solid having any plane rectilinear figure for its base, and all its sides, more or less, terminating in a point, called its *vertex*, or *summit*.

A *Cylinder* is a circular solid, having a uniform diameter, and equal and parallel circles for its end.

A *Cone* is a solid, having a circle for its base, and a true taper therefrom to its vertex.

Conic Sections are the figures made by a plane cutting a cone; they are the *ellipse*, *parabola*, and *hyperbola*.

An *Ellipse*, or *oval*, is a figure generated from the section of a cone, by a plane cutting both sides of it obliquely to the base.

A *Parabola* is the section of a cone cut by a plane parallel to one of its sides.

A *Hyperbola* is the section of a cone cut by a plane making a greater angle with the base than the side of the cone makes.

A *Conoid* is a solid generated by the revolving of a parabola or hyperbola around its axis.

A *Spheroid* is a solid generated by the revolving of an ellipse about either of its axis or diameter.

The *Transverse*, or *major*, axis of an ellipse is its longest diameter, or the distance, lengthwise, through the centre.

The *Conjugate*, or *minor*, axis of an ellipse is the shorter of the two diameters—a right line bisecting the transverse. If the generating ellipse revolves about its major axis, the spheroid is *prolate*, or *oblong*; if about its minor axis, it is *oblate*, or flattened.

An *Ordinate* is a right line drawn from any point of the curve of a conic section to either of its diameters, and perpendicular to that diameter. Either semi-diameter of an ellipse, or other conic section, may be an ordinate. It is the sine of the arc, in the equation of the circle.

The *Abscissæ* of a conic section are the parts of either diameter or axis, lying between the respective vertices and an ordinate.

The *Parameter—latus rectum* of a parabola—is a third proportional to any diameter and its conjugate. In the parabola it is a third proportional to any abscissa and its ordinate, extended through the diameter to the opposite side.

The *Focus* is the point in the axis where the ordinate is equal to half the parameter.

A *Sphere*, or *globe*, is a perfectly round substance—a solid contained under a curved surface, every point of which is equally distant from a point within, called the centre. Its axis, or diameter, is any right line passing from a side through the centre to the opposite side. A hemisphere is half a sphere.

A *Frustum* of any solid figure, as of a cone, pyramid, etc., is the part remaining after a segment has been cut off.

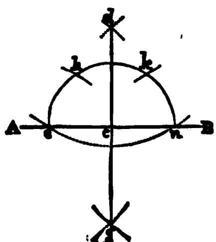
An *Ungula* is the section of a cylinder cut off by a plane oblique to the base.

The *Slant Height* of a regular figure is the length of one of its sides, or the distance from the outline of its base to its vertex, or summit.

To Bisect or Divide a Line, A B, into Two Equal Parts.

Set one foot of the dividers in A, and with the other extended so as to reach somewhat beyond the middle of the line, describe arcs above and below the line; then, with the foot of the dividers in B, describe arcs crossing the former; a line drawn from the intersection of the arcs above the line to the intersection of those below, will divide the line into two equal parts.

To erect a perpendicular on a given point in a straight line, or to draw a line at a right angle to another line.



Set one foot of the dividers in the given point *c*, and with the other extended to any convenient distance, as to A, mark equal distances on each side *c*, as *c* A, *c* B; and from A and B as centres, with the dividers extended to a distance somewhat greater than that between *c* and A, or *c* and B, describe arcs cutting each other above the line, as at *d*; a line drawn from the intersection of the arcs *d*, to the point *c*, will be perpendicular to the line A B, or will form a right angle with the line *c* A, or *c* B.

From a Point, *d*, to Let Fall a Line Perpendicular to Another Line, A B.

Set one foot of the dividers in *d*, and with the other extended so as to reach beyond the line A B, describe an arc cutting the line A B, in *e* and *n*; then with one foot of the dividers in *e*, and the other extended to more than half the distance between *e* and *n*, describe the arc *g*; then with one foot of the dividers in *n*, describe an arc cutting the arc *g* in *g*; a line drawn from the point *d* through *c* to the intersection of the arcs at *g*, will be the perpendicular required.

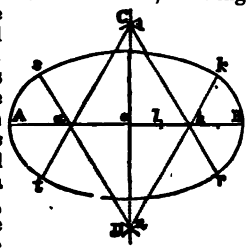
To Erect a Perpendicular upon the End of a Line, as at *c*, on the Line A *c*.

Set one foot of the dividers in *c*, and, at any convenient radius, describe the arc *e h k*; with one foot of the dividers in *e*, cut the arc in *h*, and with

one foot in *h*, cut it in *k*; from *h* as a centre, and *k* as a centre, describe arcs cutting each other at *d*; a line drawn from the intersection of the arcs, *d*, to the point *c*, will be perpendicular to the line A *c*.

To Describe an Ellipse of Given Length and Breadth.

Let the line A B equal the given length, or transverse diameter, and the line C D the conjugate, and let these lines bisect each other, forming right angles, on either side, as at *e*. Lay off the distance C D on the line A B, as from A to *l*, and divide the distance *l* B into three equal parts. From *e*, on the line A B, set off two of the parts each way, as *e a*, *e h*; and from *a*, or *h*, designate the distance *a h* on the line C D, as at *i* and *n*; from *i* draw the lines *i t* and *i r*, and from *n*, the lines *n s* and *n k*, passing through the points *a* and *h*, and cutting each other therein. From the point *n*, as a centre describe the arc *s k*, and from *i*, as a centre, the arc *r t*; also, from *a*, as a centre, describe the arc *t s*, and from *h*, as a centre, the arc *k r*, and the required ellipse is drawn.



Note.—An architrave of any depth desired may be readily described on the above.

WEIGHT OF METALS IN PLATE.

Sheet Copper. Thickness, etc.

Unit of size 4 feet by 2 feet.

70 lb. plate - -	=3-16 in.	11½ lb. plate - -	=1-32 in.
46¼ " " - -	=⅛ "	6 " " - -	=1-64 "
23 " " - -	=1-16 "		

Sheet Lead.

Unit of size 1 square foot.

15 lb. sheet -	=¼ in. thick.	6 lb. sheet - -	=1-10 in. th.
11 " -	=3-16 " "	4 " - -	=1-16 "
7½ " -	=⅛ " "		

The weight of a square foot one inch thick of

Malleable Iron, - - - - -	=40.554 lbs.
Penn. plate, - - - - - -	=40.464 "
Cast iron, - - - - - -	=37.584 "
Copper, wrought - - - - -	=46.240 "
" cast - - - - - -	=45.771 "
Brass, plate - - - - - -	=44.812 "
Zinc, cast, pure, - - - - -	=35.734 "
" sheet - - - - - -	=37.448 "
Lead, cast - - - - - -	=59.125 "
Steel, - - - - - -	=40.829 "

And for any other thickness, greater or less, it is the same in proportion; thus, a square foot of sheet copper 1-16 of an inch thick=46.24÷16=2.89 lbs. And 5 square feet at that thickness=2.89×5=14.45 lbs., etc. So, too, 5 square feet at 2½ inches thickness=46.24×2.5×5=578 lbs.

THERMOMETERS.

	Boiling Point.	Freezing Point.
Fahrenheit=	212°	32°
Centigrades=	100°	0°
Reaumur=	80°	0°

Let F=No. of degrees Fahrenheit.
" C= " " " Centigrade.
" R= " " " Reaumur.

Then, to convert

Fah. to Cent.

$$\frac{5(F-32)}{9}=C$$

Cent. to Fah.

$$\frac{9\ C}{5}+32=F.$$

Fah. to Reaum.

$$\frac{4(F-32)}{9}=R$$

Reaum. to Fah.

$$\frac{9\ R}{4}+32=F.$$

CURRENCY OF THE UNITED STATES.

(FEDERAL.)

10 mills=1 cent, 10 cents=1 dime, 10 dimes=1 dollar.

GOLD.—PURE.

The commercial or monetary value of pure gold, compared with that of an equal weight of pure silver, varies slightly in different countries. In Great Britain and some others, the standard ratio is as 15 11-27 to 1. In the United States it is as 16 to 1; and the standard gold and silver coins of the United States, coined since August, 1834, have a ratio value to each other corresponding to that of the pure metals.

24	carats fine = pure gold.	
1	grain = 4 9-29 cents	= $0.0431.
$23\frac{1}{5}$	"	= $1.00.
1	dwt. = 1 1-29	= $1.0345.
1	ounce=$20 20-29	= $20.6896.

MINT GOLD.—U. S.

(*Alloy, half each, silver and copper.*)

Nine parts pure gold and one part alloy.

21 3-5	carats fine	= Standard coin.
1	grain =3 113-129 cents	= $0.0887.
25 4-5	"	= 1.00.
1	dwt. =93 1-43 cents	= .9302.
1	ounce =$18 26-43	= 18.6046.

SILVER.—PURE.

12	ounces fine = pure silver.	
1	dwt. = 6 27-58 cents	= $0.0646.
271 1-5	grains	= 1.00.
1	ounce=$1 17-58	= 1.2931.

MINT SILVER.—U. S.

(*Alloy, all copper.*)

Nine parts pure silver and 1 part alloy, or

10 oz. 16 dwts. fine	=	Standard coin.
1 dwt.=5 27-33 cents	=	$0.0582.
471½ grains	=	1.00
1 ounce=$1 9-55	=	1.1636.

GOLD.

Denominations.	Wt. Gr.	Amount for which a Legal Tender
Double Eagle.	516.	Gold coin of all denominations is a legal tender for any amount.
Eagle........	258.	
HalfEagle.....	129.	
Three Dollars.	77.4	
Quarter Eagle.	64.5	
Dollars.......	25.8	
Eagle, prior to 1834........	270.	
Half Eagle. pr. to 1834......	135.	

SILVER.

Denominations.	Wt. Gr.	Amount for which a Legal Tender
Stand. Dollars	412.5	Unlimited.
Trade Dollars.	420.	Not legal tender
Dollars.......	412.5	Unlimited.
Half Dollars..	192.9	Ten dollars.
Quar. Dollars.	96.45	" "
Twenty Cents.	77.16	Five "
Dimes........	38.58	Ten "
Half-Dimes...	19.29	Five "
Three Cents..	11.52	" "

NICKLE AND BRONZE.

Five Cents....	77.16	25 cents.
Three Cents..	30.	25 cents.
Two cents....	96.	25 cents.
Cents.........	48.	25 cents.

Mutilated silver and minor coins should be refused as there is no provision for their redemption.—[Underwood's Reporter.

INTEREST RULES.

In addition to the rules and tables, several short methods are given:—

Take half the amount in dollars, as cents it will be the interest per month at 6%.

For finding the interest on any principal for any number of days. The answer in each case being in cents, separate the two right hand figures of the answer to express it dollars and cents:

Four per cent. Multiply by the number of days and divide by 90.
Five per cent. Multiply by the number of days and divide by 72.
Six per cent. Multiply by the number of days, separate the right-hand figure, and divide by 6.
Seven per cent. Multiply by the number of days and divide by 52.
Eight per cent. Multiply by the number of days and divide by 45.
Nine per cent. Multiply by the number of days; separate the right-hand figure and divide by 4.
Ten per cent. Multiply by the number of days and divide by 36.
Fifteen per cent. Multiply by the number of days, and divide by 24.
Eighteen per cent. Multiply by the number of days; separate the right-hand figure, and divide by 2.
Twenty per cent. Multiply by the number of days, and divide by 18.

Compound Interest.

The rule for calculating compound interest is to add the interest to the principal, and calculate the interest on the sum. The use of the following table will shorten this tedious process. It gives the amount for one dollar at 5, 6 and 7 per cent., for from 1 to 20 years.

Multiply the amount for $1 by the given number of dollars, and the product is the answer.

TABLE

Showing the Amount of $1 at Compound Interest for any Number of Years, not Exceeding Twenty.

Years.	5 per cent.	6 per cent.	7 per cent.
1	1.050000	1.060000	1.070000
2	1.102500	1.123600	1.144900
3	1.157625	1.191016	1.225043
4	1.215506	1.262477	1.310796
5	1.276282	1.338226	1.402552
6	1.340096	1.418519	1.500730
7	1.407100	1.503630	1.605781
8	1.477455	1.593848	1.718186
9	1.551328	1.689479	1.838459
10	1.628895	1.790848	1.967151
11	1.710339	1.898299	2.104852
12	1.795856	2.012196	2.252192
13	1.885649	2.132928	2.409845
14	1.979932	2.260904	2.578534
15	2.078928	2.396558	2.759032
16	2.182875	2.540352	2.952164
17	2.292018	2.692773	3.158815
18	2.406619	2.854339	3 379932
19	2.526950	3.025600	3.616526
20	2.653298	3.207135	3.869684

Note.—The above table is available for British money by reading pounds and decimals of a pound, for dollars and decimals of dollars.

To find the time in which any sum will double itself at compound interest, at any rate not exceeding 10% per annum.

Rule.—Divide 70 by the rate of interest, and take the whole number nearest the quotient. This is the number of years.

Rate.		Years.
3	70÷3=	23
4	70÷4=	17
5	70÷5=	14
6	70÷6=	12
7	70÷7=	10
8	70÷8=	9
9	70÷9=	8
10	70÷10=	7

LONG OR LINEAR MEASURE.—U. S.

STANDARD. A brass rod, the length of which at 62° Fahrenheit is $\frac{36.0000}{39.1393}$ that of a pendulum beating seconds in vacuo, at the level of the sea, at the latitude of London,$=\frac{36.0000}{39.1013}$ at 32° Fah., at the gravitation at New York=the yard.

6 points..................=1 line.	5½ yards (16½ ft.).....=1 rod.
12 lines (72 points).......=1 inch	40 rods 220 yds.)....=1 furlong.
12 inches................=1 foot.	8 fur. (5280 ft.)......=1 stat. mile
3 feet (36 in.)...........=1 yard	

SPECIAL, FOR CLOTH.

2¼ inches ....=1 nail.	4 quarters (36 in.).......=1 yard.
4 nails (9 inches).....=1 quarter.	

SPECIAL, FOR LAND.

7 92-100 inches..........=1 link.	100 links (66 feet)......=1 chain.
25 links............=1 rod.	80 chains (320 rods)...=1 s. mile.

ENGINEER'S CHAIN.

10 inches.......................=1 link.
120 links (100 feet).............=1 chain.

WIRE GAUGE.

The diameter of

No. 1 wire is............5-16 inch.	No. 11 wire is.........⅛ inch.
" 4 " ....¼ "	" 16 " ....1-16 "
" 7 " ....3-16 "	" 22 " ....1-32 "

MISCELLANEOUS.

Hair's breadth.....=1-48 inch.	Fathom...............=6 feet.
Digit............=10 lines.	Knot.................=47⅞ feet.
Palm..............= 3 inches.	Cable's length........=120 fath.
Hand.............= 4 "	Geometrical pace.....=4.4 feet.
Span...........= 9 "	

12 particular things.........=1 dozen.
12 dozen (144).............=1 gross.
12 gross (1728).............=1 great gross.
20 particular things.........=1 score.
24 sheets of paper..........=1 quire.
20 quires..................=1 ream.

SQUARE OR SUPERFICIAL MEASURE.

(*Length* × *Breadth.*)

144	square inches	=1	square foot.
9	" feet	=1	" yard.
30¼	" yards	=1	" rod.
40	" rods	=1	rood.
4	roods	=1	acre.

Special, for Land.

$62\frac{454}{625}$ square inches	=	1 square link.
10000 " links	=	1 " chain.
10 " chains	=	1 " acre.
Square rod	=	$272\frac{1}{4}$ square feet.
Rood	=	1210 " yards. 10890 " feet.
Acre (160 sq. rods)	=	4840 " yards. 43560 " feet.
Square mile	=	640 acres. 102400 sq. rods.

220×198	square feet		= 1 acre.
The square of 40	" rods		
" " " 69.5701	" yards		
" " " 208.710321	" feet		

A township	is 6 miles square	=36 sections.
A section	" 1 " "	=640 acres.
$\frac{1}{4}$ "	" $\frac{1}{2}$ " "	=160 "
1-16 "	" $\frac{1}{4}$ " "	= 40 "

Circular Measure.

Minute, or Geographical m. (60″) = 1.152 s. miles. 6085 feet.	Great circle = 360 degrees.
League = 3 miles.	Equatorial circumference of the earth. = 24893 s. m.
Degree = 60 geo. miles. 69.148 s. ms.	Equatorial diam. = 7924 "
Sign (1-12 zod.) = 30 degrees.	Polar diam. = 7898 "
	Mean radius = 3956 "

Note.—In the expressions, square feet and feet square, there is this difference; viz., the former expresses an area in which there are as many square feet as the number named, and the latter an area in which there are as many square feet as the square of the number named. The former particularizes no form of area, the latter asserts a square form.

Cubic or Solid Measure.—U. S.

(*Length × breadth × depth.*)

Cubic foot. 1728 cubic inches,	=	1.273 cylindrical feet. 2200 " inches. 3300 spherical " 6600 conical "
Cylindrical foot. 1728 " inches,	=	0.785398 cubic feet. 1357.2 " inches. 2592 spherical " 5184 conical "
27 cubic feet	=	1 cubic yard.
50 " of round timber	=	1 ton.
42 " of shipping "	=	1 "
40 " of hewn "	=	1 "
128 "	=	1 cord.
Cubic foot of pure water, at the maximum density at the level of the sea, (39°.83, barometer 30 in.)	=	$62\frac{1}{2}$ avoirdupois pounds. 1000 " ounces.

Cylindrical foot............ =	49.1 avoirdupois	pounds.
	785.4 "	ounces.
Cubic inch................ =	0.036169 "	pounds.
	0.5787 "	ounces.
	253.1829 "	grains.
Cylindrical inch............ =	0.028415 "	pounds.
	0.4546 "	ounces.
Pound..................... =	27.648 cubic inches.	
" distilled.............. =	27.7015 " "	
Cubic inch distilled......... =	252.6839 grains.	
Pound at 62° " .... =	27.7274 cubic inches.	
Cubic inch at 62° distilled... =	252.458 grains.	
" " " 60° in *vacuo*... =	252.722 "	

Cubic foot of salt water (sea) weighs 64.3 pounds.

GENERAL MEASURE OF WEIGHT.—U. S.

Avoirdupois.

Standard. — The pound is the weight, taken in air, of 27.7015 cubic inches of distilled water at its maximum density, (39°.83 F., the barometer being at 30 inches)=27.7274 cubic inches of distilled water at 62°=7000 Troy grains.

27 11-32 grains..........=1 dram.
16 drams (437½ grs.).....=1 ounce.
16 ounces (7000 grs.)....=1 pound.

Special.—Gross.

28 pounds......=	1 quarter.
4 quarters =	1 quintel.
112 pounds. =	1 cwt.
20 cwt.........=	1 ton.

Special.—Troy.

(Exclusively for gold and silver bullion, precious stones, and gold. silver and copper coins, and with reference to their monetary value only.)

24 grains.............=1 pennyw't.
20 dwts. (480 grs.)....=1 ounce.
12 oz. (5760 grs.).....=1 pound.

Special.—Apothecaries.

(Exclusively for compounding medicines, for recipes and prescriptions.)

20 grains...............=1 scruple.
3 scruples.............=1 dram.
8 drams (480 g.).......=1 ounce.
12 oz. (5760 g.).........=1 pound.

LIQUID MEASURE.—U. S.

The "Wine" or "Winchester" Gallon, of 231 cubic inches capacity, is the Government or Customs gallon of the United States for all liquids, and the legal gallon of each state in which no law exists fixing a state or statute gallon of its own. It contains 58372¼ grains distilled water at 39°.83, the barometer being at 30 inches.

4 gills = 1 pint, 2 pints = 1 quart.

4 quarts, or 231 cubic in. 0.13368 cub. ft., 294.1176 cyl. in.	=	1 gallon. 8.355 av'd. lbs. pure water.
Liquid gallon of the state of New York, 281.62 cylindric in.	=	0.128 cubic foot. 221.184 " inches. 8 avoid. lbs. pure water at 39°.83, b. 30 in.
Imperial gallon, 277.274 cub. in.	=	10 av'd. lbs. distilled water at 62° F., b. 30 in.

Barrel	=31½ gallons.	Puncheon	= 84 gallons.
Tierce	=42 "	Pipe or Butt	=126 "
Hogshead	=63 "	Tun	=252 "

Ale gallon, 282 cub. in. } = { 10 1-5 av'd. lbs. pure water at 39°.83, b. 30 in.

1 wine gallon = { 0.8331 Imperial gallons. 0.8191 Ale " 1.0444 New York "

1 Imperial gallon	=1.2	Wine gallon.
1 Ale "	=1.221	" "
1 New York "	=0.9575	" "
1 " " "	=0.7977	Imp. "
1 Imperial "	=1.2536	N. Y. "

DRY MEASURE.—U. S.

The "Winchester Bushel," so called, of 2150 42-100 cubic inches capacity, is the government bushel of the United States, and the legal bushel of each state having no special or statute bushel of its own. The standard Winchester bushel measure is a cylindrical vessel having an outside diameter of 19½ inches, an inside diameter of 18½ inches, and an inside depth of 8 inches. The standard "heaped" or "coal" bushel of England was this measure heaped to a true cone 6 inches high, the base being 19½ inches, or equal to the outside diameter of the measure. Its ratio to the even bushel was, therefore, as 1.28, nearly, to 1. The present "Imperial" measure of England has the same outside diameter and the same depth as the Winchester, and an internal diameter of 18.8 inches, and the same height of cone is retained for forming the heaped bushel. Its ratio, therefore, to the even bushel is a trifle less than was that of the Winchester. In the United States the "heaped bushel" is usually estimated at 5 even pecks, or as 1.25 to 1 of the standard even bushel, which, if taken as the rule, requires a cone on the Winchester measure of 5.4 inches to equal the heaped Winchester bushel.

4 gills	=	1 pint.
2 pints	=	1 quart.
4 quarts	=	1 gallon, or half peck.
8 quarts	=	1 peck.
4 pecks / 2150.42 cubic inches / 1.244456 " feet / 1.5844 cyl. "	=	1 bushel. / 2738 cyl. inches. / 77.7785 avoirdupois pounds. pure water.
Bushel of the state of New York / 2816.1955 cyl. in	=	1.28 cubic feet. / 2211.84 " inches. / 80 av'd. lbs. pure water.
Bushel of Connecticut	=	1.272 cubic feet. / 2198 " inches. / 79.50 av'd. lbs. pure water.
Heaped Win. bushel / 1.28—even " "	=	2747.7 cubic inches. / 1.59 " feet.
Imperial bushel	=	2218.192 " inches.
Chaldron	=	36 Winchester heaped bushels.

1 Winchester bushel	=	0.9722 New York bushel.		
		0.9784 Conn.		"
		0.9694 Imperial		"
1 New York bushel	=	1.02856 Winchester bushel.		
1 Connecticut "	=	1.0221	"	"
1 Imperial "	=	1.0315	"	"
1 New York "	=	0.9971	Imp.	"
1 Conn. "	=	0.9909	"	"
1 Imperial "	=	1.0029	N. Y.	"
1 " "	=	1.0092	Conn.	"
1 New York "	=	1.0063	"	"
1 Conn. "	=	0.99374	N. Y.	"

SPECIFIC GRAVITIES.

The specific gravity of a body is its weight relative to the weight of an equal bulk of pure water at the maximum density (39°.83, b. 30 in.), the water being taken as 1., a cubic foot of which weighs 1000 avoirdupois ounces, or 62½ lbs. The specific gravity, therefore, of any body multiplied by 1000, or, which is the same thing, the decimal being carried to three places of figures, or thousands, as in the following tables, the whole taken as an integer equals the number of ounces in the cubic foot of the material; multiplied by 62.5, or considered an integer and divided by 16, it equals the number of pounds in a cubic foot; and multiplied by .036169, or taken as an integer and divided by 27648, it equals the decimal fraction of a pound per cubic inch; by which it is readily seen, the specific gravity of a commodity being known, its weight per any given bulk is easily and accurately ascertained; as also, its specific gravity, the weight and bulk being known. The weight of any one article relative to that of any other, is as its respective specific gravity to the specific gravity of the other.

METALS.	Spe. Grav.
Antimony	6.712
Arsenic	8.310
Bismuth	9.823
Bronze	8.700
Brass, com.	8.604
Copper, cast	8.788
" wire-drawn	8.878
Cadmium	8.604
Cobalt	7.700
Chromium	5.900
Glucinium	3.000
Gold, pure, cast	19.258
" pure, hammered	19.546
Iridium	15.363
Iron, cast	7.209
" wrought	7.787
Lead	11.352
Mercury, 32°	13.598
" 60°	13.580
" —39°	15.000
Manganese	8.013
Molybdenum	8.611
Nickel	8.280
Osmium	10.000
Platinum, cast	19.500
Platinum, hammered	20.337
" rolled	22.069
Potassium, 60°	0.865
Palladium	11.870
Rhodium	11.000
Silver, pure, cast	10.474
" hammered	10.511
Sodium	0.970
Steel, soft	7.836
" tempered	7.818
Tin, cast	7.291
Tellurium	6.115
Tungsten	17.600
Titanium	4.200
Uranium	9.000
Zinc, cast	6.861

STONES AND EARTH.	
Alabaster, white	2.730
" yellow	2.699
Amber	1.078
Asbestos, starry	3.073
Borax	1.714
Bone, ox	1.656
Brick	1.900

	Spe. Grav.
Chalk, white	2.782
Charcoal	.441
" triturated	1.380
Cinnabar	7.786
Clay	1.934
Coal, bitum. avg	1.270
" anth. "	1.520
Coral, red	2.700
Earth, loose	1.500
Emery	4.000
Feldspar	2.500
Flint, white	2.594
" black	2.582
Garnet	4.085
Glass, flint	2.933
" white	2.892
" plate	2.710
" green	2.642
Granite, red	2.625
" Lockport	2.655
" Quincy	2.652
" Susquehanna	2.704
Grindstone	2.143
Gypsum, opaque	2.168
Hone, white	2.876
Hornblende	3.600
Ivory	1.822
Jasper	2.690
Limestone, green	3.180
" white	3.156
Lime, compact	2.720
" foliated	2.837
" quick	0.804
Loadstone	4.930
Magnesia, hyd	2.333
Marble, common	2.686
" white Ital	2.708
" Rutland, Vt	2.708
" Parian	2.838
Nitre, crude	1.900
Pearl, oriental	2.656
Peat, hard	1.329
Porcelain, China	2.385
Porphyra, red	2.766
" green	2.675
Quartz	2.647
Rock Crystal	2.654
Ruby	4.283
Stone, common	2.520
" paving	2.416
" pumice	0.915
" rotten	1.981
Salt, common, solid	2.130
Saltpeter, refined	2.090
Sand, dry	1.800
Serpentine	2.430

	Spe. Grav
Shale	2.600
Slate	2.672
Spar, fluor	3.156
Stalactite	2.324
Talc, black	2.900
Topaz	4.011

SIMPLE SUBSTANCES,

Neither Metallic nor Gaseous.

Boron	1.968
Bromine	2.970
Carbon	3.521
Iodine	4.948
Phosphorus	1.770
Selenium	4.320
Silicon	1.184
Sulphur	1.990

WOODS.—*Dry.*

Apple	0.793
Alder	.800
Ash	.845
Beech	.850
Birch	.720
Box, French	1.328
Box, Dutch	.912
Cedar	.561
Cherry	.715
Chestnut	.610
Cocoa	1.040
Cork	.240
Cypress	.644
Ebony, American	1.331
" foreign	1.290
Elm	.671
Fir, yellow	.657
" white	.569
Hacmetac	.592
Hickory, red	.900
Lignum vitæ	1.333
Larch	.544
Logwood	.913
Mahogany, Spanish, best	1.065
" " com	.800
" St. Domingo	.720
Maple, red	.750
Mulberry	.897
Oak, live	1.120
" white	.785
Orange	.705
Pear	.661
Pine, white	.554
" yellow	.568
Poplar, white	.383
Plum	.785
Quince	.705

	Spe. Grav.
Spruce, white	.551
Sassafras	.482
Sycamore	.604
Walnut	.671
Willow	.585
Yew, Spanish	.807
" Dutch	.788

Highly Seasoned American.

Ash, white	.722
Beech	.624
Birch	.526
Cedar	.452
Cherry	.606
Cypress	.441
Elm	.600
Fir	.491
Hickory, red	.838
Maple, hard	.560
Oak, white, upland	.687
" James River	.759
Pine, yellow	.541
" pitch	.536
" white	.473
Poplar, (tulip)	.587
Spruce, white	.495

Gums, Fats, Etc.

Asphaltum	.905 / 1.650
Beeswax	.965
Butter	.942
Camphor	.988
Gamboge	1.222
Gunpowder	.900
" shaken	1.000
" solid	1.550 / 1.800
Gum, Arabic	1.454
" Caoutchouc	.938
" Mastic	1.074
Honey	1.450
Ice	.930
Indigo	1.009
Lard	.941
Pitch	1.150
Rosin	1.100
Spermaceti	.943
Starch	1.530
Sugar, dry	1.606
Tallow	.938
Tar	1.015

Liquids.

	Spe. Grav.
Acid, acetic	1.062
" citric	1.034
Acid, fluoric	1.060
" nitric	1.485
" nitrous	1.420
" sulphuric	1.846
" muriatic	1.200
" silicic	2.660
Alcohol, anhy	.794
" 90%	.834
Beer	1.034
Blood, human	1.054
Camphene, pure	.863
Cider, whole	1.018
Ether, sulph	.715
" nitric	.908
Milk, cow's	1.032
Molasses, 75%	1.400
Oils, linseed	.934
" olive	.917
" rapeseed	.927
" sassafras	1.090
" turpentine, com	.875
" sperm, pure	.874
" whale, purified	.923
Proof spirits	.925
Vinegar	1.025
Water, pure	1.000
" sea	1.026
" Dead sea	1.240
Wine, champagne	.997
" claret	.994
" port	.997
" sherry	.992

Elastic Fluids.

The measure of which is atmospheric air, at 60°, b. 30 in., its assumed gravity 1; one cubic foot of which weighs 527.04 grains.=.305 of a grain per cubic inch. It is at this temperature and density, to pure water at the maximum density, as .0012046 to 1, or as 1 to 830.1.

Simple or Elementary Gases.

Hydrogen	.0689
Oxygen	1.1025
Nitrogen	.9760
Fluorine	
Chlorine	2.470
Carbon, vapor of, (theoretically)	4.24

Compound Gases.

Ammoniacal	.591
Carbonic acid	1.525
" oxide	.763
Carbureted hydrogen	.559

	Spe. Grav.		Spe. Grav.
Chloro-carbonic	3.389	Sulphureted	1.177
Cyanogen	1.818	Steam, 212°	.490
Muriatic acid gas	1.247	Smoke, of wood	.900
Nitrous " "	3.176	" of coal	.102
" oxide "	1.040	Vapor, of water	.623
Olefiant	.982	" of alcohol	1.613
Phosphureted hydrogen	1.185	" of spirits turpentine	5.013

WEIGHT PER BUSHEL (EVEN WINCHESTER) OF DIFFERENT GRAINS, SEEDS, ETC., ETC.

Articles.	Lbs.	Articles.	Lbs.
Barley	47	Hemp seed	48
Beans	63	Oats	32
Buckwheat	46	Peas	64
Blue-grass seed	14	Rye	56
Corn	56	Salt, T. I.,	80
Cranberries		" boiled	56
Clover seed	60	Timothy seed	56
Dried apples	22	Wheat	60
" peaches	33	Potatoes, h'p'd	60
Flax seed	52		

NUMBER OF NAILS (BY COUNT), IRON MACHINE CUT, OF DIFFERENT DESCRIPTIONS, IN A POUND.

Description.	No.	Description.	No.
3 penny	600	10 penny	88
4 "	360	12 "	68
6 "	200	20 "	40
8 "	110		

METRIC SYSTEM.

By an Act of Congress, approved in July, 1867, the use of the Weights and Measures of the Metric System is permissible; and contracts are declared not to be invalid because of the weights and measures expressed or referred to therein are of that system.

The metre was designed to be the ten-millionth ($\frac{1}{10,000,000}$) part of the earth's meridian passing through Dunkirk and Formentera. Later investigations, however, based on additional measures of meridional arcs in other parts of the world have shown that the metre sensibly exceeds such ten-millionth part. Sir John Herschel states this excess to be one part in 6400.

The METRE is the unit or base of the measure of length, the ARE of that of surface, the STERE of cubic, the GRAMME of that of weight, and the LITRE of that of capacity.

The Metre	=39.371	U. S. inches.
" Are 100 sq. Metres	=3.95387	" square rods.

The Stere / 1 cubic Metre	=	35.31714 U. S. cubic feet.
" Litre / 1 cu. Decimetre	=	61.02803 " " inches. / 2.11352 " wine pints.
" Gramme	=	15.43815 Troy grains.

The fractional divisions of each of these units are expressed by the same prefixes, viz., *milli*, *centi*, *deci*; and the multiples of each by *deca*, *hecto*, *kilo*, *myria*;—thus *milli*gramme, *centi*gramme, etc., *milli*metre, *centi*metre, etc. To illustrate with the metre—

10 *milli*metres ....= 1 *centi*metre.
10 centimetres ....= 1 *deci*metre.
10 decimetres ....= 1 metre.
10 metres ....= 1 *deca*metre.
10 decametres ....= 1 *hecto*metre.
10 hectometres ....= 1 *kilo*metre.
10 kilometres ....= 1 *myria*metre.

TABLE

EXHIBITING THE WEIGHT IN POUNDS OF ONE FOOT IN LENGTH OF WROUGHT OR ROLLED IRON OF ANY SIZE, (CROSS SECTION,) FROM ⅛ INCH TO 12 INCHES, SQUARE BAR.

Size in Inches.	Weight in Pounds.	Size in Inches.	Weight in Pounds.	Size in Inches.	Weight in Pounds.	Size in Inches.	Weight in Pounds.
⅛	.053	2⅜	19.066	4⅝	72.305	7¾	203.024
¼	.211	2½	21.120	4¾	76.264	8	216.336
⅜	.475	2⅝	23.292	4⅞	80.333	8¼	230.068
½	.845	2¾	25.560	5	84.480	8½	244.220
⅝	1.320	2⅞	27.939	5⅛	88.784	8¾	258.800
¾	1.901	3	30.416	5¼	93.168	9	273.792
⅞	2.588	3⅛	33.010	5⅜	97.657	9¼	289.220
1	3.380	3¼	35.704	5½	102.240	9½	305.056
1⅛	4.278	3⅜	38.503	5⅝	106.953	9¾	321.332
1¼	5.280	3½	41.408	5¾	111.756	10	337.920
1⅜	6.390	3⅝	44.418	5⅞	116.671	10¼	355.136
1½	7.604	3¾	47.534	6	121.664	10½	372.672
1⅝	8.926	3⅞	50.756	6¼	132.040	10¾	390.628
1¾	10.352	4	54.084	6½	142 816	11	408.960
1⅞	11.883	4⅛	57.517	6¾	154.012	11¼	427.812
2	13.520	4¼	61.055	7	165.632	11½	447.024
2⅛	15.263	4⅜	64.700	7¼	177.672	11¾	466.684
2¼	17.112	4½	68.448	7½	190.136	12	486.656

To determine the weight, in pounds, of one foot in length, or of any length, of a bar of any of the following metals of form prescribed, of any size, multiply the weight in pounds, of an equal length of square rolled iron of the same size, (see table of square rolled iron,) if the weight be sought of

Iron, Round rolled, by .... .7854
Steel, Square " " 1.0064
" Round " " .... .7904
Cast iron. Square bar " .... .9258

Cast iron,	Round bar,	by	.7271
Copper,	Square rolled,	"	1.1422
"	Round "	"	.8971
Brass,	Square "	"	1.105
"	Round "	"	.8679
Bronze,	Square bar,	"	1.1173
"	Round "	"	.8775
Lead,	Square "	"	1.4579
"	Round "	"	1.145

The weight of a bar of any metal, or other substance, of any given length, of a flat form (and any other form may be included in the rule), is readily obtained by multiplying its cubic contents (feet or inches) by the weight (pounds, ounces or grains) of a cubic foot or inch of the article sought to be weighed; that is—

Length × breadth × thickness × weight per unity of measure.

For the weight in pounds of a cubic foot or inch of different metals, (see table of "Weights of Metals per Measure of Solidity, etc.")

Or, for Flat or Square Bar.

Multiply the sectional area in inches by the length in feet, and that product, if the metal be

Wrought iron,	by	3.3795
Cast "	"	3.1287
Steel,	"	3.4

Example:—Required the weight of a bar of steel, whose length is 7 feet, breadth 2½ inches, and thickness ¾ of an inch.

$2.5 \times .75 \times 7 \times 3.4 = 44.625$ lbs. *Ans.*

Example:—Required the weight of a cast iron beam, whose length is 14 feet, breadth 9 inches, and thickness 1½ inch.

$14 \times 9 \times 1.5 \times 3.1287 = 591.32$ lbs. *Ans.*

TABLE.

Comparative Weight of Metals, Weight per Measure of Solidity.

Metals.	Spec. Grav.	Ratio of Comparison	Pounds in a Cubic Foot.	Pounds in a Cubic Inch.
Iron, wrought or rolled	7.787	1.	485.68	.28100
Cast iron	7.209	.9258	451.00	.26100
Steel, soft, rolled	7.836	1.0064	489.75	.28342
Copper, pure	8.878	1.1422	554.88	.32111
Brass, common	8.604	1.1050	537.75	.3112
Bronze, gun metal	8.700	1.1173	543.75	.31464
Lead	11.352	1.4579	709.50	.4106

TABLE

EXHIBITING THE WEIGHT OF 100 FEET IN LENGTH OF DIFFERENT NOS. OF DIFFERENT KINDS OF WIRE, WITH SIZE IN DECIMALS OF AN INCH.

No.	Size in Dec'ls	Iron. Lbs.	Brass. Lbs.	Copper. Lbs.
1	.300	25.924	28.646	29.610
2	.284	22.580	24.951	25.791
3	.259	19.469	21.514	22.238
4	.238	16.589	18.331	18.949
5	.220	13.940	15.403	15.922
6	.203	11.520	12.730	13.159
7	.180	9.332	10.311	10.658
11	.120	4.147	4.582	4.737
16	.065	1.037	1.145	1.184
22	.028	.2592	.2864	.2961
30	.012	.0518	.0572	.0592

NOTE.—To convert the decimal of a pound into ounces, multiply it by 16; thus, the weight of 100 feet of No. 22 iron wire, is $.2592 \times 16 = 4.1472$ ounces.

WEIGHT OF PIPES.

The weight of one foot in length of any pipe, of any diameter and thickness, may be ascertained by multiplying the square of its exterior diameter, in inches, by the weight of 12 cylindrical inches of the material of which the pipe is composed, and by multiplying the square of its interior diameter, in inches, by the same factor and subtracting the product of the latter from that of the former, the remainder or difference will be the weight. This is evident from the fact that the process obtains the weight of two solid cylinders of equal length (one foot), the diameter of one being that of the pipe, and the other that of the vacancy, or bore. For very large pipes, the dimensions may be taken in feet, and the weight of a cylindrical foot of the material used as the factor, or multiplier, if desired.

The weight of 12 cylindrical inches (length 1 ft., diameter 1 in.) of

Malleable iron........................	= 2.6543	lbs.
Cast iron............................	= 2.4573	"
Copper, wrought......................	= 3.0817	"
Lead, "	= 3.8697	"
Cast iron—1 cyl. foot—...............	= 353.86	"

Therefore—EXAMPLE.—Required the weight of a copper pipe whose length is 5 feet, exterior diameter $3\frac{1}{4}$ inches, and interior diameter 3 in.

$$3\tfrac{1}{4} = \tfrac{13}{4} \times \tfrac{13}{4} = 10.5625 \times 3.0317 = 32.022+$$
$$3 \times 3 = 9 \times 3.0317 \qquad = 27.285+$$

Ans. $4.737 \times 5 = 23.685$ pounds.

EXAMPLE.—Required the weight of a cast iron pipe, whose length is 10 feet, exterior diameter 38 inches, and interior diameter 3 feet.

$38^2 \times 2.4573 - 36^2 \times 2.4573 = 363.68 \times 10 = 3636.8$ lbs. *Ans.*

Or, $\overline{38^2 - 36^2} = 148 \times 2.4573 = 363.68 \times 10 = 3636.8$ lbs. *Ans.*

EXAMPLE.—Required the weight of a lead pipe, whose length is 1200 feet, exterior diameter ⅞ of an inch, and interior diameter 9-16 of an inch.

$\frac{7}{8}\times\frac{7}{8}=\frac{49}{64}=.765625$, and $\frac{9}{16}\times\frac{9}{16}=\frac{81}{256}=316406$, and $.765625-.316406=449219\times3.8697\times1200=2086$ lbs. *Ans.*

EXAMPLE.—The length of a cast iron cylinder is 1 foot, its exterior diameter is 12 inches, and its interior diameter 10 inches; required its weight.

$12^2-10^2=44\times2\ 4573=108.12$ lbs. *Ans.*

Or, 144 : 353.86 :: 44 : 108.12 lbs. *Ans.*

TABLE

SHOWING THE COEFFICIENTS OF WEIGHT, IN POUNDS, OF ONE FOOT IN LENGTH, OF VARIOUS THICKNESS, OF DIFFERENT KINDS OF PIPE, OF ANY DIAMETER WHATEVER.

Thickness in Inches.	Wrought Iron	Copper.	Lead.
1-32	.332	.379	.484
1-16	.664	.758	.9675
3-32	.995	1.137	1.451
⅛	1.327	1.516	1.935
5-32	1.658	1.894	2.417
3-16	1.99	2.274	2.901
7-32	2.323	2.653	3.386
¼	2.654	3.032	3.87
5-16	3.318	3.79	4.837
⅜	3.981	4.548	5.805

CAST IRON.

Thickness.	Factor.	Thickness.	Factor.	Thickness.	Factor.
3-16	1.842	⅝	6.143	1¼	12.287
¼	2.457	¾	7.372	1½	14.744
⅜	3.686	⅞	8.6	1¾	17.201
½	4.901	1	9.829	2	19.659

To obtain the weight of pipes by means of the above table—

RULE.—Multiply the diameter of the pipe, taken from the interior surface of the metal on the one side to the exterior surface on the opposite (interior diameter+thickness), in inches, by the number in the table under the respective metal's name, and opposite the thickness corresponding to that of the pipe—the product will be the weight, in pounds, of one foot in length of the pipe, and that product multiplied by the length of the pipe, in feet, will give the weight for any length required.

EXAMPLE.—Required the weight of a copper pipe whose length is 5 feet, interior diameter and thickness 3⅛ inches, and thickness ⅛ of an inch.

$3\frac{1}{8}=25\text{-}8=3.125\times1.516\times5=23.687$ lbs. *Ans.*

EXAMPLE.—Required the weight of a cast iron pipe, 10 feet in length, whose interior diameter is 3 feet, and whose thickness is 1 inch.

$36+1=37\times9.829\times10=3636.73$ lbs. *Ans.*

NOTE. For each joint, add 1 foot in length of pipe.

GAUGING.

RULES—For finding the capacity in gallons or bushels of different shaped Cisterns, Bins, Casks, etc., and also, by way of examples, for constructing them to given capacities.

RULE 1. When the vessel is rectangular. Multiply the interior length, breadth, and depth, in feet together, and the product by the capacity of a cubic foot, in gallons or bushels, as desired for its capacity.

RULE 2. When the vessel is cylindrical. Multiply the square of its interior diameter in feet, by its interior depth in feet, and the product by the capacity of a cylindrical foot in gallons or bushels, as desired for its capacity.

RULE 3. When the vessel is a rhombus or rhomboid. Multiply its interior length in feet, its right-angular breadth in feet, and its depth in feet together, and the product by the capacity of a cubic foot in the special measure desired for its capacity.

RULE 4. When the vessel is a frustum of a cone—a round vessel larger at one end than the other, whose bases are planes. Multiply the interior diameter of the two ends together, in feet, add ⅓ the square of their difference in feet to the product, multiply the sum by the perpendicular depth of the vessel in feet, and that product by the capacity of a cylindrical foot in the unit of measure desired for its capacity.

RULE 5. When the vessel is a prismoid or the frustum of any regular pyramid. To the square root of the product of the areas of its ends in feet, add the areas of its ends in feet, multiply the sum by ⅓ its perpendicular depth in feet, and that product by the capacity of a cubic foot in gallons or bushels, as desired by its capacity.

If it is found more convenient to take the dimensions in inches, do so; proceed as directed for feet, divide the product by 1728, and multiply the quotient by the capacity of the respective foot as directed. Or, multiply the capacity in inches by the capacity of the respective inch in gallons or bushels: by the quotient obtained by dividing the capacity of the respective foot in gallons or bushels by 1728 for the contents.

RULE 6. When the vessel is a barrel, hogshead, pipe, etc. Multiply the difference in inches between the bung diameter and head diameter, (interior,) if the staves be

much curved	by .7
medium curved	by .68
straighter than medium	by .6
nearly straight	by .55

and add the product to the head diameter, taken in inches; then multiply the square of the sum by the length of the cask in inches, and divide the product by the capacity in cylindrical inches of a gallon or bushel as desired for the contents. Or, divide the contents in cylindrical inches, as above found, by 1728, and multiply the quotient by the capacity of a cylindrical foot in gallons or bushels as desired for its contents. Or, multiply the capacity in cylindrical inches by the capacity of a cylindrical inch, in gallons or bushels, as desired,—that is, by the quotient obtained by dividing the capacity of a cylindrical foot in gallons or bushels, by 1728, for the contents.

The capacity of

Cubic Foot=		Cylindrical Foot=	
7.4805 Winchester wine	gallons.	5.8752 Winchester wine	gallons.
7.8125 New York liquid	"	6.1359 New York liquid	"
6.1276 Ale	"	4.8126 Ale	"
6.2321 Imperial	"	4.8947 Imperial	"
.80356 Winchester	bushels.	.6311 Winchester	"
.78125 New York	"	.6136 New York	"
.78617 Connecticut	"	.61746 Connecticut	"
.779 Imperial	"	.51183 Imperial	"

MENSURATION OF LUMBER.

To find the contents of a board:

RULE.—Multiply the length in feet by the width in inches, and divide the product by 12; the quotient will be the contents in square feet.

EXAMPLE.—A board is 16 feet long and 10 inches wide; how many square feet does it contain?

$$16 \times 10 = 160 \div 12 = 13\ 4\text{-}12. \quad \textit{Ans.}$$

To find the contents of a plank, joist or stick of square timber.

RULE.—Multiply the product of the depth and width in inches by the length in feet, and divide the last product by 12; the quotient is the contents in feet.

EXAMPLE.—A joist is 16 feet long, 5 inches deep, and 2½ inches wide; how many feet does it contain?

$$5 \times 2.5 \times 16 \div 12 = 16\ 8\text{-}12. \quad \textit{Ans.}$$

To measure round timber.

RULE (in general practice.)—Multiply the length, in feet, by the square of ¼ the girt, in inches, taken about ⅓ the distance from the larger end, and divide the product by 144; the quotient is the contents in cubic feet.

EXAMPLE.—A stick of round timber is 40 feet in length, and girts 56 inches; how many cubic feet does it contain?

$$56 \div 4 = 14 \times 14 = 196 \times 40 \div 144 = 54.44 \text{ feet.} \quad \textit{Ans.}$$

OF CONDUITS OR PIPES.

To find the requisite thickness of a pipe, of any diameter, equal to the support of a given head of water.

RULE.—Multiply the head, in feet, by the diameter of the pipe, in inches, and divide the product by the reliable cohesive force, per square inch, of the material of which the pipe is composed; the quotient will be the required thickness.

NOTE. The reliable cohesion of a material is not above ⅓ its ultimate force, as given in the Table of Cohesive Forces. By experiment, it has been found that a cast iron pipe 15 inches in diameter and ¾ of an inch thick, will support a head of water of 600 feet; and that one of the same diameter made of oak, and 2 inches thick, will support a head of 180 feet—12000 lbs. per square inch for cast iron, 1200 for oak, 750 for lead, are counted safe estimates. The ultimate cohesion of an alloy, composed of lead 8 parts, and zinc 1 part, is 3000 pounds per square inch.

Concerning the Discharge of Pipes, etc.

Small pipes, whether vertical, horizontal, or inclined, under equal heads, discharge proportionally less water than large ones. That form of pipe, therefore, which presents the least perimeter to its area, other things being equal, will give the greatest discharge. A round pipe, consequently, will discharge more water in a given time than a pipe of any other form, of equal fluid.

The greater the length of a pipe discharging vertically, the greater the discharge. Because the friction of the particles against its sides, and consequent retardation, is more than overcome by the gravity of the fluid.

The greater the length of a pipe discharging horizontally, the less proportionally will be the discharge. The proportion compared with a less length is in the inverse ratio of the square root of the two lengths, nearly.

Other things being equal, rectilinear pipes give a greater discharge than curvilinear, and curvilinear greater than angular. The head, the diameters and the lengths being the same, the time occupied in passing an equal quantity of water through a straight pipe is 9, through one curved semi-circle 10, and through one having one right angle, otherwise straight, 14. All interior inequalities and roughness should be avoided.

It has been ascertained that a velocity of 60 feet a minute (1 foot a second) through a horizontal pipe, 4 inches in diameter and 100 feet in length, is produced by a head 2 1-7 inches, only 1-7 of an inch above the upper surface of the orifice; and that, to maintain an equal velocity through a pipe similarly situated, of equal length, having a diameter of ½ inch only, a head of 1 5-12 feet is required. To increase the velocity through the last mentioned pipe to 2 feet a second, requires a head 4 10-12 feet; to 3 feet, a head of 10 1-12; to 4 feet, a head of 17 10-12, etc.

From the foregoing, the following, it is believed, reliable rules, are deduced:

To find the velocity of water passing through a straight horizontal pipe of any length and diameter, the head, or height of the fluid above the centre of the orifice, being known.

Rule.—Multiply the head, in feet, by 2500, and divide the product by the length of the pipe in feet, multiplied by 13.9, divided by the interior diameter of the pipe in inches; the square root of the quotient will be the velocity in feet per second.

Example.—The head is 6 feet, the length of the pipe 1340 feet, and its diameter 5 inches; required the velocity of the water passing through it.

$$2500 \times 6 = 15000 \div \left(\frac{1340 \times 13.9}{5}\right) = \sqrt{4.03} = 2 \text{ feet per second. } \textit{Ans.}$$

To find the head necessary to produce a required velocity through a pipe of given length and diameter.

Rule.—Multiply the square of the required velocity, in feet, per second, by the length of the pipe multiplied by the quotient obtained by dividing 13.9 by the diameter of the pipe in inches, and divide the product thus obtained by 2500; the quotient will be the head in feet.

Example.—The length of a pipe lying horizontal and straight is 1340 feet, and its diameter is 5 inches; what head is necessary to cause the water to flow through it at the rate of 2 feet a second?

$$2^2 \times 1340 \times \frac{13.9}{5} \div 2500 = 6 \text{ feet. } \textit{Ans.}$$

To find the quantity of water flowing through a pipe of any length and diameter.

RULE.—Multiply the velocity in feet per second by the area of the discharging orifice, in feet, and the product is the quantity in cubic feet discharged per second.

EXAMPLE.—The velocity is 2 feet a second, and the diameter of the pipe 5 inches; what quantity of water is discharged in each second of time?

$5 \div 12 + .4166$, and $.4166^2 \times .7854 \times 2 = .273$ cubic foot. *Ans.*

MISCELLANEOUS PROBLEMS.

To Ascertain the Cost of Hay.

RULE.—Multiply the number of pounds by half the price per ton, and remove the decimal point three places to the left.

EXAMPLE.—What is the cost of 824 lbs. of hay at $16 per ton?

$16 \div 2 = 8 \times 824 = 6.592$. *Ans.*—$6.59.2.

NOTE. The above rule applies to anything of which 2000 lbs. is a ton.

To Measure Grain.

RULE.—Level the grain; ascertain the space it occupies in cubic feet. Multiply the number of cubic feet by 8, and point off one place to the left.

NOTE. Exactness requires the addition to every 3 hundred bushels of 1 extra bushel.

The foregoing rule may be used for finding the number of gallons, by multiplying the number of bushels by 8.

RULE.—If the grain be corn in the car, divide the answer by 2 to find the number of bushels of shelled corn.

Rapid Rules for Measuring Land without Instruments.

The first thing to ascertain is the contents of any given plot in square yards; then the number of yards being given, find out the number of rods and acres.

The most ancient and simplest manner is a step. An ordinary sized man can train himself to cover 1 yard at a stride, on the average, with sufficient precision for ordinary purposes.

To make use of this means of measuring distances, it is essential to walk in a straight line. To do this, fix the eye on two objects in a line straight ahead, one comparatively near. the other remote, and in walking keep these objects constantly in line.

A Convenient Measure for Inches.

A man about 5 feet 10 inches high will span 9 inches from tip of thumb to tip of little finger; 6 inches from end of thumb to outer edge of hand. A man of any height will span about the same from end of right middle finger to end of left.

This rule is generally applicable except in cases of deformity.

For Grindstones.

Sometimes they are sold by weight, at other times by measure.

RULE.—If by weight, square the diameter, in inches, multiply by thickness, in inches, then by the decimal .06363; the product will be the weight of the stone in pounds.

If by measure in square feet or inches.

RULE.—Add the diameter to half the diameter, multiply the sum by the same half, multiply the product by the thickness, divide the last (if feet is required) product by 1728 for the answer.

For Squaring the Sills of a Frame, or Laying Out Two Right Angle Lines.

Measure 8 feet from the corner on one sill or line and on the other 6 feet, place a 10-foot pole across the hypothenuse and bring the sill or line at the points marked, so that the 10-foot pole will be the right length between the points mentioned.

To Find the Specific Gravity of a Body Heavier than Water.

RULE.—Weigh the body in water and out of water, and divide the weight out of water by the difference of the two weights.

EXAMPLE.—A piece of metal weighs 10 lbs. in atmosphere, and but $8\frac{1}{4}$ in water; required its specific gravity.

$$10-8.25=1.75, \text{ and } 10\div1.75=5.714. \quad \textit{Ans.}$$

To Find the Specific Gravity of a Body Lighter than Water.

RULE.—Weigh the body in air; then connect it with a piece of metal whose weight, both in and out of water, is known, and of sufficient weight that the two will sink in water; and find their combined weight in water; then divide the weight of the body in air by the weight of the two substances in air, less the sum of the difference of the weight of the metal in air and water and the combined weight of the two substances in water, and the quotient will be the specific gravity sought.

EXAMPLE.—The combined weight, in water, of a piece of wood and piece of metal is 4 lbs.; the wood weighs in atmosphere 10 lbs.; and the metal in atmosphere 12, and in water 11 lbs.; required the specific gravity of the wood.

$$10\div\overline{10+12-12 \backsim 11+4}=.588. \quad \textit{Ans.}$$

To Find the Specific Gravity of a Fluid.

RULE.—Multiply the known specific gravity of a body by the difference of its weight in and out of the fluid, and divide the product by its weight out of the fluid; the quotient will be the specific gravity of the fluid in which the body is weighed.

EXAMPLE.—The specific gravity of a brass ball is 8.6; its weight in atmosphere is 8 oz., and in a certain fluid $7\frac{1}{4}$ oz., required the specific gravity of the fluid.

$$8-7.25=.75, \text{ and } 8.6\times.75=6.45, \text{ and } 6.45\div8=.806. \quad \textit{Ans.}$$

To find the proportion of one to the other of two simples forming a compound or the extent to which a metal is debased, (the metal and the alloy used being known.)

EXAMPLE.—The specific gravity of gold is 19.258, and that of copper, 8.788; an article composed of the two metals has a specific gravity of 18: in what proportion are the metals mixed?

$$18 \backsim 19.258 \times 8.788 = 11.055$$
$$18 \backsim 8.788 \times 19.258 = 177.4, \text{ then}$$

$$\left.\begin{array}{l} \overline{11.055 + 177.4} : 11.055 :: 18 = 1.056 \text{ copper.} \\ \overline{11.055 + 177.4} : 177.4 :: 18 = 16.944 \text{ gold.} \end{array}\right\} \textit{Ans.}$$

Or, 18—1.056=16.944 gold. Copper to gold as 1 to 16.04+.

To Find the Lifting Power of a Balloon.

RULE.—Multiply the capacity of the balloon, in feet, by the difference of weight between a cubic foot of atmosphere and a cubic foot of the gas used to inflate the balloon, and the product is the weight the balloon will raise.

EXAMPLE.—A balloon, whose diameter is 24 feet, is inflated with hydrogen; what weight will it raise?

Specific gravity of air is 1, weight of a cubic foot 527.04 grains; specific gravity of hydrogen is .0689.
$527.04 \times .0689 = 36.31$ grains=weight of 1 cubic foot of hydrogen.
$527.04 - 36.31 = 490.73$ grains=difference of weight of air and hydrogen.
$24^3 \times .5236 = 7238.24$=capacity in cubic feet of balloon.
Then, $7238.26 \times 490{,}73 = 3552021$ grs. $= \frac{3552021}{7000} = 507\frac{4}{10}$ lbs. *Ans.*

To find the Diameter of a Balloon that shall be Equal to the Raising of a Given Weight.

The weight to be raised is 507 4-10 lbs.

$\overline{507. \times 7000} \div 490.73 = 7238.24$, and $7238.24 \div .5236 = \sqrt[3]{13824} = 24$ feet. *Ans.*

To Find the Thickness of a Concave or Hollow Metallic Ball or Globe, that shall have a Given Buoyancy in a Given Liquid.

EXAMPLE.—A concave globe is to be made of brass, specific gravity 8.6, and its diameter is to be 12 inches; what must be its thickness that it may sink exactly to its centre in pure water?

Weight of a cubic inch of water .036169 lb.; of the brass .3112 lb.
Then, $\overline{12^3 \times .5236 \times .036169} \div 2 = 16.3625$ cubic inches of water to be displaced.

$16.3625 \div .3112 = 52.5787$ cubic inches of metal in the ball.

$\overline{12^2 \times 3.1416} = 452.39$ square inches of surface of the ball.

And, $52.5787 \div 452{\cdot}39 = .1162 + = 1{\cdot}9$ inch, thick, full. *Ans.*

To cut a Square Sheet of Copper, Tin, etc., so as to form a Vessel of the Greatest Cubical Capacity the Sheet Admits of.

RULE.—From each corner of the sheet, at right angles to the side, cut 1-6 part of the length of the side, and turn up the sides till the corners meet.

Comparative Cohesive Force of Metals, Woods and other substances, Wrought Iron (medium quality) being the unit of comparison, or 1; the Cohesive Force of which is 60000 lbs. per inch, cross section.

Wrought Iron	1.00	Steel, fine	2.25
" " wire	1.71	Tin, cast block	.88
Copper, cast	.54	Zinc, "	.048
" wire	1.02	" sheet	.27
Gold, cast	.34	Brass, cast	.75
" wire	.51	Gun metal	.50
Iron, cast (average)	.56	Gold 5, copper 1	.83
Lead, "	.016	Silver 5, " 1	.80
" milled	.055	Brick	.05
Platinum, wire	.88	Slate	.20
Silver, cast	.66	Ash, white	.23
" wire	.68	" red	.30
Steel, soft	2.00	Beech	.19

Birch	.25	Pine, pitch	.20
Box	.33	Sycamore	.22
Cedar	.19	Walnut	.30
Chestnut, sweet	.17	Willow	.22
Cypress	.10	Ivory	.27
Elm	.22	Whalebone	.13
Locust	.34	Marble	.15
Mahogany, best	.36	Glass, plate	.16
Maple	.18	Hemp fibres, glued	1.53
Oak, Amer. white	.19		

The strength of white oak to cast iron, is as 2 to 9.
The stiffness " " " " " is as 1 to 13.

To determine the weight, or force, in pounds, necessary to tear asunder a bar, rod, or piece of any of the above named substances, of any given cross section.

RULE.—Multiply the comparative cohesive force of the substance, as given in the table, by the cohesive force per square inch, area of cross section (60000 lbs.) of wrought iron, which gives the cohesive force of 1 square inch area of cross section of the substance whose power is sought to be ascertained, and the product of 1 square inch thus found, multiplied by area of cross section, in inches, of the rod, piece, or bar itself, gives the cohesive force thereof.

Alloys having a Tenacity Greater than the Sum of their Constituents.

Swedish copper	6 pts.,	Malacca tin 1;	tenacity	per	square	inch,	64000	lbs.
Chili "	6 "	" "	"	"	"	"	60000	"
Japan "	5 "	Banca "	"	"	"	"	57000	"
Anglesea "	6 "	Cornish "	"	"	"	"	41000	"
Com. block-tin	4 "	lead 1, zinc "	"	"	"	"	13000	"
Malacca tin	4 "	regulus of antimony 1;		"	"	"	12000	"
Block-tin	8 "	lead 1 part;	tenacity	"	"	"	10000	"
Block-tin	8 "	zinc 1 "	"	"	"	"	10200	"
Zinc	1 "	lead 1 "	"	"	"	"	4500	"

Alloys having a Density Greater than the Mean of their Constituents.

Gold with antimony, bismuth, cobalt, tin or zinc.
Silver with antimony, bismuth, lead, tin or zinc.
Copper with bismuth, palladium, tin or zinc.
Lead with antimony.
Platinum with molybdinum.
Palladium with bismuth.

Alloys having a Density Less than the Mean of their Constituents.

Gold with copper, iron, iridium, lead, nickel or silver.
Silver with copper or lead.
Iron with antimony, bismuth or lead.
Tin with antimony, lead or palladium.
Nickel with arsenic.
Zinc with antimony.

Relative Power of Different Metals to Conduct Electricity.

(The mass of each being equal.)

Copper	1000	Platinum	188
Gold	936	Iron	158
Silver	736	Tin	155
Zinc	285	Lead	83

Lime, palladium, platinum, rhodium, silex, may be melted by means of strong lenses, or hydro-oxygen blowpipe.

Melting Points of Metal and when Other Bodies Change Form.

SMELTING POINTS.	Deg. Fah.	BOILING POINTS.	Deg. Fah.
Cast iron, fully smelted	2754	Oil of Linseed,	600
Gold, fine	1983	Sweet Oil,	412
Silver, "	1850	Sulphuric Acid,	410
Copper "	2160	Sulphur,	390
Brass, common	1900	Phosphorus,	374
Zinc,	740	Oil of Turpentine,	315
Antimony,	790	Sea water, salt	217
Lead,	594	Water, distilled	212
Bismuth,	476	Alcohol, 90 per cent	174
Tin,	421	Ether, sulph	97
Solder, common	475	Benzine,	84
" plumbers	360	Naptha,	65
1 Tin, 1 Bismuth,	283	MISCELLANEOUS.	
3 Tin, 2 Lead, 5 Bismuth,	212	Iron, welding heat	2552
1 Tin, 1 Lead, 4 Bismuth,	201	Metals, Red, daylight	1077
Sulphur,	228	Common fire,	790
Phosphorus,	109	Iron, red, daylight,	884
Beeswax, white	155	" bright red in dark	752
" yellow	142	Human blood,	98
Tallow,	92	Cold greatest ever produced,	—90
Ice,	32	Vinous permentation,	—60 to 70
1 Snow, 1 Salt,	0	Acetous fermentation begins,	—78
Mercury,	—39	Acetification ends	—88
Mercury boils	656	Phosphorus burns,	—43

Relative Power of Different Bodies to Radiate Heat.

Water	100	Lead, bright	19
Copper	12	Mercury	20
Glass	90	Paper, white	100
Ice	85	Silver	12
India ink	88	Tin, blackened	100
Iron, polished	15	" clean	12
Lampblack	100	" scraped	16

NOTE. The power of a body to reflect heat is inverse to its power of radiation.

Boiling Point of Liquids.

(Barometer at 30 in.)

Acid, nitric	253°	Oils, essential, avg	318°
" sulphuric	600°	" turpentine	316°
Alcohol, anhyd	168.5°	" linseed	640°
" 90%	174°	Phosphorus	554°
Ether, sulph	97°	Sulphur	560°
Mercury	656°	Water	212°

NOTE. Barometer at 31 inches, water boils at 213°.57; at 29, it boils at 210°.38; at 28, it boils at 208°.69; at 27, it boils at 206°.85, and in vacuo it boils at 88°. No liquid, under pressure of the atmosphere alone, can be heated above its boiling point. At that point the steam emitted sustains the weight of the atmosphere.

Freezing Point of Liquids.

	Deg.		Deg.
Acid, nitric	—55	Oil, linseed, avg	—11
" sulphuric	1	Proof spirits	—7
Ether	—47	Spirits turpentine	16
Mercury	—39	Vinegar	28
Milk	30	Water	32
Oil, cinnamon	30	Wine, strong	20
" fennel	14	Rapeseed oil	25
" olive	36		

NOTE.—Water expands in freezing .11, or 1-9 its bulk.

Expansion of Fluids by being Heated from 32° to 212°, F.

Atmospheric air, $\frac{1}{480}$ per each degree	= .375
Gases, all kinds, $\frac{1}{480}$ " " "	
Mercury, exposed	.018
Muriatic acid, (sp. gr. 1.137,)	.060
Nitric acid, (sp. gr. 1.40,)	.110
Sulphuric acid, (sp. gr. 1.85,)	.060
" ether,—to its boiling point	.070
Alcohol, (90 per cent.,) " "	.110
Oils, fixed	.080
" turpentine	.070
Water	.046

Relative Power of Substances to Conduct Heat.

Gold	1000	Zinc	363
Silver	973	Tin	304
Copper	898	Lead	180
Platinum	981	Porcelain	012
Iron	374	Fire brick	011

NOTE. Different woods have a conducting power in ratio to each other, as are their respective specific gravities, the more dense having the greater.

Metals in Order of Ductility and Malleability.

Ductility.	*Malleability.*
1. Gold.	1. Gold.
2. Silver.	2. Silver.
3. Platinum.	3. Copper.
4. Iron.	4. Tin.
5. Copper.	5. Platinum.
6. Zinc.	6. Lead.
7. Tin.	7. Zinc.
8. Lead.	8. Iron.

Quantity per cent. by Weight of Nutritious Matter Contained in different Articles of Food.

Articles.	Per Ct.	Articles.	Per Ct.
Lentils	94	Wheat	85
Peas	93	Barley	83
Beans	92	Rice	88
Corn, (maize,)	89	Rye	79

Articles.	Per. Ct.	Articles.	Per. Ct.
Oats	74	Carrots	10
Meats, avg	35	Cabbage	7
Potatoes	25	Greens	6
Beets	14	Turnips, white	4

SPECIFIC GRAVITY, AND QUANTITY PER CENT., BY VOLUME, OF ABSOLUTE ALCOHOL CONTAINED, NECESSARY TO CONSTITUE THE FOLLOWING NAMED UNADULTERATED ARTICLES.

Articles.	Sp. grav. 60°, b. 30.	Per ct. of Alcohol.
Absolute alcohol, (anhydrous)	.7939	100.
Alcohol, highest by distillation	.825	92.6
" commercial standard	.8335	90.
Proof Spirits,—standard	.9254	54.

QUANTITY PER CENT. BY VOLUME (GENERAL AVERAGE) OF ABSOLUTE ALCOHOL CONTAINED IN DIFFERENT PURE OR UNADULTERATED LIQUORS, WINES, ETC.

Liquors, etc.	Per Cent.	Wines.	Per Cent.
Rum	50	Port	22
Brandy	50	Madeira	20
Gin. Holland	48	Sherry	18
Whiskey, Scotch	50	Lisbon	17
" Irish	50	Claret	14
Cider, whole	9	Malaga	16
Ale	8	Champagne	11
Porter	4	Burgundy	12
Brown Stout	6	Muscat	17
Perry	9	Currant	19

PROOF OF SPIRITUOUS LIQUORS.

The weight, in air, of a cubic inch of Proof Spirits, at 60° F., is 233 grains; therefore. an inch cube of any heavy body, at that temperature, weighing 233 grains less in spirits than in air, shows the spirits in which it is weighed to be proof. If the body lose less of its weight, the spirit is above proof,—if more, it is below.

COMPARATIVE WEIGHT OF DIFFERENT KINDS OF TIMBER IN A GREEN AND PERFECTLY SEASONED STATE.

Assuming the weight of each kind destitute of water to be 100, that of the same kind green is as follows:—

Ash	139	Cedar	132	Maple, red	128
Beech	139	Elm, swamp	178	Oak, Am	135
Birch	130	Fir, Amer	145	Pine, white	139

NOTE.—Woods which have been felled, cleft and housed for 12 months still retain from 20 to 25 per cent. of water. They, therefore, contain but from 75 to 80 per cent. of heating matter; and it will require from 23 to 29 per cent. the weight of such woods to dispel the water they contain. They, therefore, less valuable by weight, as fuel, by this per cent., than woods perfectly free from moisture. They never, however, contain, exposed to an ordinary atmosphere, less than 10 per cent. of water, however long kept; and even though rendered anhydrous by a strong heat, they again imbibe, on exposure to the atmosphere, from 10 to 12 per cent. of dampness.

RELATIVE POWER OF DIFFERENT SEASONED WOODS, COALS, ETC., AS FUEL, TO PRODUCE HEAT—THE WOODS SUPPOSED TO BE SEASONED TO MEAN DRYNESS (77½ PER CENT.), AND THE OTHER ARTICLES TO CONTAIN BUT THEIR USUAL QUANTITY OF MOISTURE.

	Ratio Heating Power per equal	
	Bulk.	Weight.
Hickory, shell-bark	1.00	1.00
" red-heart	.81	.99
Ash, white	.77	.98
Beech, red	.65	.99
Chestnut	.49	.98
Elm, white	.58	.98
Maple, hard	.60	.98
Oak, white	.81	.99
" red	.69	.99
Pine, white	.42	1.01
" yellow	.48	1.03
Birch, black	.63	.99
" white	.48	.99
Coal, Cumberland (bit.)	2.41	2.28
" Lackawanna (anth.)	2.07	2.22
" Lehigh "	2.17	2.03
" Newcastle (bit.)	1.91	1.96
" Pictou, "	2.01	1.91
" Pittsburg, "	1.62	1.82
" Peach Mountain (anth.)	2.48	2.29
Charcoal	1.14	2 53
Coke, Virginia, natural	1.71	2.12
" Cumberland	1.19	2.25
Peat, ordinary		.62
Alcohol, common		2.02
Beeswax, yellow		2.90
Tallow		3.10

NOTE.—By help of the preceding table, the price of either one article being known, the relative or par value of either other, as fuel, may be readily ascertained:

EXAMPLE.—Maple (60) : \$5.00 :: Pine (42) : \$8.50.

ILLUMINATION.—ARTIFICIAL.

The great advantages of petroleum, which led to so sudden a revolution in the system of artificial illumination all over the world, causing the old lamps designed for whale, sperm, and vegetable oils and for camphene to be thrown aside and to be replaced by the new lamps, are the cheapness of this oil, the brilliancy of the light, and the freedom of the flame from smoke.

Although the first oil was struck in Colonel Drake's well on Oil Creek, as recently as August 28, 1859, or only *eleven years ago, the average daily production in the United States has now reached the enormous amount of 22,000 barrels of over forty gallons each.

The wells on Oil Creek now run more oil in a fortnight than was captured per annum by the entire fleet of six hundred vessels which sailed

*This report is dated 1871. The price of petroleum products now, 1884, is less than half of what it was at that time.

from Nantucket, New Bedford, Stonington, New London, and Providence in the palmiest days of the whale fishery. .

The results of a series of experiments made by Dr. J. G. Pohle, E. G. Kelly, and the writer, a committee of judges for the American Institute Fair, is plainly not out of place here, as giving an exact basis for a comparison of kerosene oil with other illuminating materials.

The standard of comparison is a sperm candle which burns two grains per minute, or 120 grains per hour. The oils tested were entered for competition, and are the safest oils in the market, as is shown by the following statement of their flashing and burning points:

	Specific gravity Deg. Beaumé.	Flaming point. Inflammable vapor evolved.	Burning Point. Oil takes fire.
Required by Board of Health Ord.	....	100° F.	110° F.
Standard Kerosene.	46° B.	115	128
Astral Oil	49	125	138
Mineral Sperm	36	262	300

The "Standard Kerosene" and "Astral Oil" are superior varieties of kerosene. The "Mineral Sperm" is a much heavier oil and is not what is generally known as kerosene. It is not well adapted for flat wick lamps, as, when the level of the oil in the reservoir of the lamp is two or three inches below the flame, the oil is not readily drawn up by the flat wicks. In argand burners, which have a circular wick, and in which the reservoir is placed at one side so high that the oil is brought near the level of the flame, the supply is maintained and the flame retains its original size and brilliancy as long as there is any oil in the lamp.

The following table shows the rate of consumption and illuminating power of these oils:

RATE OF CONSUMPTION AND ILLUMINATING POWER OF PETROLEUM OILS.

NAME OF THE OIL.	Hours required to burn 1 gal of oil.	Average candle power of the flame.	Lbs. of candles equal to one gallon oil.	Hours requir'd to burn 1 gal. at rate of 8 candles pow'r
I.—Low glass lamp, $\frac{5}{8}$-inch flat wick—				
Standard kerosene	200	4.26	14.54	106.5
Astral oil	179.5	4.77	14.67	107
II.—High glass lamp, $\frac{5}{8}$-inch flat wick.				
Standard kerosene	109	8.9	16.6	121
Astral oil	112	7.7	14.38	108
III.—German student lamp, argand circular wick—				
Standard kerosene	69	14.7	17.44	127
Astral oil	81.6	11.1	15.57	113
Mineral sperm	90	11.6	17.85	130
IV.—Merrill's patent lamp, argand circular wick—				
Standard kerosene	94.5	12.	19.38	142
Astral oil	102.5	11.47	20.17	147
Mineral sperm	105.5	11.88	21.14	156

From these figures it appears that in lamps of the sizes generally used, the illuminating power of the kerosene flame is equal to from eight to nine sperm candles, with the flat wick, and to from eleven to fifteen candles, with the round wick, and that a gallon of oil lasts from 70 to 109 hours in such lamps, and gives an amount of light equivalent to that which is afforded by from 14½ to 20 pounds of sperm candles.

The heavy Mineral Sperm oil adds to the advantage of a degree of safety almost equal, in fact practically equal, to whale oil, that of giving an amount of light equal to about 21½ lbs. sperm candles.

The ordinary gas burner, burning five feet of gas per hour, gives, if the gas is of good quality, a light equal to 16 candles.

From these figures it follows, therefore, that

One gallon Standard Kerosene is equivalent, at 40 cents per gallon, to,

In flat wick lamp,	302	feet gas,	costing	$0.91
German student lamp,	317	"	"	0.95
Merrill's lamp,	355	"	"	1.06
Average	325	"	"	0.97

One gallon Astral oil is equivalent, at 50 cents per gallon, to

In flat wick lamp,	295	feet gas,	costing	$0.88
German student lamp,	282	"	"	0.85
Merrill's lamp,	367	"	"	1.10
Average,	315	"	"	0.94

One gallon Mineral Sperm is equivalent, at 75 cents a gallon, to

In German student lamp,	325	feet gas,	costing	$0.97
Merrill's lamp,	390	"	"	1.17
Average,	358	"	"	1.07

One thousand feet, 16-candle gas, costing $3.00, is equivalent to

3.25	gals.	common kerosene,	flashing at	86° F.,	costs,	at 30 cts.	a gal.	$0.97
3.08	"	standard	"	115 F.,	"	40	"	1.23
3.17	"	Astral oil	"	125 F.,	"	50	"	1.58
2.80	"	Mineral sperm,	"	262 F.,	"	75	"	2.10

The average cost per hour of light equal to eight sperm candles, is

From sperm candles, at 42 cents per pound					5.76	cents.
Gas, at $3 per 1000 feet					0.75	"
Mineral sperm oil, in	German st'd't	lamp,	at 75	cts. per gal.	0.57	"
" "	Merrill's	"	" "	"	0.48	"
Astral oil,	flat wick	"	50 "	"	0.46	"
"	German st'd't	"	" "	"	0.44	"
"	Merrill's	"	" "	"	0.34	"
Standard kerosene, in	flat wick	"	40 "	"	0.33	"
"	German st'd't	"	" "	"	0.31	"
"	Merrill's	"	" "	"	0.28	"
Common kerosene, unsafe, in	flat wick	lamp,	30 "	"	0.27	"

In addition to the advantages of economy, brilliancy, cleanliness, and absence of smoke, it should be mentioned that kerosene never freezes, and never becomes rancid. The only real objection, but, nevertheless, a most serious objection, raised against kerosene, is the danger arising from its inflammability, and the combustible vapors which are evolved at ordinary temperatures by most of the oils in common use.

The oils used in the experiments above narrated do not belong to this class; they are perfectly safe, and it can be shown that every refiner has it

in his power to manufacture a safe oil at an expense of not over three to five cents per gallon more than it costs him to make the dangerous oil now generally sold. It is, moreover, shown in the last table, that the difference in the cost of the same amount of light when obtained from safe or unsafe oils, burned in flat wick lamps, between standard kerosene, which flashes at 115° F., and is safe, and common oil which flashes at 86° F. (the average of the unsafe oils sold in New York), is only six one-hundredths of a cent per hour, or one cent for sixteen hours.

Certainly an illuminating material which gives, in a cheap lamp, an amount of light equal to that of eight sperm candles, at a cost of one-third of a cent an hour, is an inestimable boon to the world. It adds several hours to the length of the day, and enables the working-classes to devote the long evenings to the improvement of their minds by reading; or where the labors of the day must be prolonged into the night, it saves the eyes from the inevitable ruin which would follow the use of insufficient light. The sanitary advantages of a clear, smokeless light are inestimable. Without attempting to follow out all the good influences which may be attributed to the new illuminating material, it is safe to say that petroleum is one of the great civilizing agents of the nineteenth century.—[C. F. Chandler, Ph. D.

The consumption of 1.43 cubic feet of gas per hour gives a light equal to one wax candle, the consumption of 1.96 cubic feet per hour, a light equal to 4 wax candles, and the consumption of 3 cubic feet per hour a light equal to 10 wax candles. A cubic foot of gas weighs 518 grains.

The average yield of bi-carbureted hydrogen—olefiant gas—coal gas, obtained from the following articles, is as annexed:

1 pound	bituminous coal	4½	cubic feet.
1 "	oil, or oleine	15	" "
1 "	tar	12	" "
1 "	resin, or pitch	10	" "

A pipe whose interior diameter is ½ inch will supply gas equal in illuminating power to 40 wax candles.

VELOCITY AND FORCE OF WIND.

Appellations.	Mean velocity in Miles per hour.	Mean velocity in Feet per second.	Force in lbs. per sq. foot.
Just perceptible	2½	3⅔	.032
Gentle, pleasant wind	4½	6⅔	.101
Pleasant, brisk gale	12½	18⅓	.80
Very brisk gale	22½	33	2.52
High winds	32½	47⅔	5.23
Very high wind	42½	62⅓	8.92
Storm, or tempest	50	73⅓	12.30
Great storm	60	88	17.71
Hurricane	80	117⅓	31.49
Tornado, moving buildings, etc.	100	146.7	49.20

The curvature of the earth is 6.99 inches (.5825 foot) in a single statute mile, or 8.05 inches in a geographical mile, and is as the square of the distance for any distance greater or less, or space between two levels; thus, for 3 statute miles it is

$$1 : 3^2 :: 6.99 : 5\tfrac{1}{4} \text{ feet, nearly.}$$

The horizontal refraction is 1-13.

Degrees of longitude are to each other in length as the cosines of their latitudes. At the equator a degree of longitude is 60 geographical miles in length, at 90° of latitude it is 0; consequently, a degree of longitude at

5°	=59.77 miles.	40°	=45.96 miles.
10°	=59.09 "	50°	=38.57 "
20°	=56.38 "	70°	=20.52 "
30°	=51.96 "	85°	= 5.23 "

Time is to longitude 4 minutes to a degree, or 5.785 minutes per hundred statute miles—faster, east of any given point; slower, west.

The mean velocity of sound at the temperature of 33° is 1110 feet a second. Its velocity is increased ½ a foot a second for every degree above 33°, and decreased ½ a foot a second for every degree below 33°.

In water sound passes at the rate of 4708 feet per second.

Light travels at the rate of 192,000 miles per second.

GRAVITATION.

A body falling freely from rest will descend 16 1-12 feet in the first second of time, and at the end of that time will have acquired a velocity which will carry it through 32 1-6 feet in the next second of time, and so on.

Velocities of falling bodies, therefore, are as the times, the spaces fallen through, as the square of the times, and the space fallen through in each time, as 1, 3, 5, 7, etc., that fallen through in the first space of time. Thus, in 10 seconds, a body will fall $10^2 \times 16$ 1-12=1608⅓ feet; the velocity which it will have acquired at the end of that time will be 10×32 1-6=321⅔ feet per second, and the space fallen through during the last second will be 19×16 1-12=305 7-12 feet. The above is strictly true as regards all bodies one with another, great or small, compact or porous, falling in vacuo; and is sufficiently near the truth for all practical purposes as between all dense bodies falling in atmosphere. Water obeys the same law in its descent, and is estimated as having the same velocity.

The time, therefore, in seconds, occupied by a body falling a given distance, is the square root of the quotient obtained by dividing the distance by 16 1-12; and the velocity in feet per second, attained at the end of any given time, is the square root of the product of the distance, or space fallen through, and the square of half of 16 1-12; thus, $1608.33 \div 16.083 = \sqrt{100} = 10$ seconds, and $1608.33 \times 64.33 = \sqrt{103463.89} = 321.66$, =velocity at end of 10 seconds.

The momentum or force with which a falling body strikes, is the product of its weight and velocity—(the weight multiplied by the square root of the product of the space fallen through and square of half of 16 1-12); thus, 100 lbs. falling 50 feet, will strike with a force

$$50 \times 8.0416^2 = \sqrt{3233.37} = 56.86 \times 100 = 5686 \text{ lbs.}$$

An entire revolution of the earth, from west to east is performed in 23 hours, 56 minutes, and 4 seconds. A solar year=365 days, 5 hours, 48 minutes, 57 seconds.

The area of the earth is nearly 197.000,000 square miles. Its crust is supposed to be about 30 miles in thickness, and its mean density 5 times that of water. About ¾ of its area, or 150.000.000 square miles, is covered by water. The portions of land in the several divisions, in square miles, are, in round numbers, as follows, viz:

Asia	17,318,000	Europe	3,781,000
Africa	11,556,000	Australia	3,425,000
America	15,480,000		

America is 9000 miles long, or .36 the circumference of the earth.

The population of the globe is about 1,381,950,609, of which there are, in

Asia	807,000,000	Africa	190,950,609
Europe	294,000,000	America	85,000,000

CHEMICAL ELEMENTS.

The chemical elements—simple substances in nature—as far as have been determined, are 58 in number: 13 non-metallic and 45 metallic.

Of the non-metallic, 5—*bromine*. *chlorine*, *fluorine*, *iodine* and *oxygen* (formerly termed "*supporters of combustion*"), have an intense affinity for all the others, which they penetrate, corrode, and apparently consume, always with the production, to some extent, of light and heat. They are all non-conductors of electricity and negative electrics.

The remaining 8—*hydrogen*, *nitrogen* or *azote*, *carbon*, *boron*, *silicon*, *phosphorus*, *selenium* and *sulphur*, are eminently susceptible of the impressions of the preceding five; when acted upon by either of them to a certain extent, light and heat are manifestly evolved, and they are thereby converted into incombustible compounds.

Of the metals, 7—*potassium*, *sodium*, *calcium*, *barytium*, *lithium*, *strontium* and *magnesia*, by the action of oxygen, are converted into bodies possessed of *alkaline* properties.

Seven of them—*glucinum*, *erbium*, *terbium*, *yttrium*, *allumium*, *zirconium*, and *thorium*, by the action of oxygen, are converted into the *earths* proper.

In short, all the metals are acted upon by oxygen, as also by most or all of the non-metallic family. The compounds thus formed are *alkaline*, *saline*, or *acidulous*, or an *alkali*, a *salt*, or an *acid*, according to the nature of the materials and the extent of combination.

Metals combine with each other, forming *alloys*. If one of the metals in combination is mercury, the compound is called an *amalgam*.

Silicon is the base of the mineral world, and *carbon* of the organized.

For a very general list of the metals, see Table of Specific Gravities, page 128.

TABLE

EXHIBITING THE ELEMENTARY CONSTITUENTS AND PER CENT. BY WEIGHT OF EACH, IN 100 PARTS OF DIFFERENT COMPOUNDS.

Compounds.	Constituents and per cent.			
	Hydrogen.	Oxygen.	Azote.	Carbon.
Atmospheric air ..... *a*		20.8	79.2	
Water, pure	11.1	88.9		
Alcohol, anhyd.	12.9	34.44		52.66
Olive oil	13.4	9.4		72.2
Sperm oil	10.97	10.13		78.9
Castor oil	10.3	15.7		74.00
Stearine (solid of fats)	11.23	6.3	0.30	82.17
Oleine (liquid of fats)	11.54	12.07	0.35	76.03
Linseed oil	11.35	12.64		76.01
Oil of turpentine	11.74	3.66		84.6
"Camphene," (pure spts. turp.)	11.5			88.5
Caoutchouc, (gum elastic)	10.			90.
Camphor	11.14	11.48		77.38
Copal, resin	9.	11.1		79.9

CONSTITUENTS OF BODIES.—Continued.

Compounds.	Constituents and per cent.			
	Hydrogen.	Oxygen.	Azote.	Carbon.
Guaiac, resin	7.05	25.07		67.88
Wax, yellow	11.37	7.94		80.69
Coals, cannel	3.93	21.05	2.80	72.22
" Cumberland	3.02	14.42	2.56	80.
" Anthracite *b*				93.
Charcoal				97.
Diamond				100.
Oak wood, dry *c*	5.69	41.78		52.53
Beech " "	5.82	42.73		51.45
Acetic acid, dry	5.82	46.64		47.54
Citric " crystals	4.5	59.7		35.8
Oxalic " dry		79.67		20.33
Malic " crystals	3.51	55.02		41.47
Tartaric " dry	3.	60.2		36.80
Formic " dry	2.68	64.78		32.54
Tannin, tannic acid, solid	4.20	44.24		51.56
Nitric acid, dry		73.85	26.15	
Nitrous acid, anhyd., liquid		61.32	30.68	
Ammoniacal gas	17.47		82.53	
Carbonic acid "		72.32		27.68
Carb. hydrogen gas	24.51			75.49
Bi-carb. hyd., olefiant gas	14.05			85.95
Cyanogen gas			53.8	46.2
Nitric oxide "		53.	47.00	
Nitrous " "		36.36	63.64	
Ether, sulphuric	13.85	21.24		65.05
Creosote	7 8	16.		76.2
Morphia	6.37	16.29	5.	72.34
Quina—quinine	7.52	8.61	8.11	75.76
Veratrine	8.55	19.61	5.05	66.79
Indigo	4.38	14.25	10.	71.37
Silk, pure white	3.94	34.04	11.33	50.69
Starch,—farina, dextrine	6.8	49.7		43.5
Sugar	6.29	50.33		43.38
Gluten	7.8	22.	14.5	55.7
Wheat *c*	6.	44.4	2.4	47.02
Rye	5.7	45.3	1.7	47.03
Oats	6.6	38.2	2.3	52.9
Potatoes	6.1	46.4	1.06	45.9
Peas	6.4	41.3	4.3	48.
Beet root	6.2	46.3	1.8	45.7
Turnips	6.	45.9	1.8	46.3
Fibrin *d*	7.03	20.30	19.31	53.36
Gelatin *d*	7.91	27.21	17.	47.88
Albumen *d*	7.54	23.88	15.70	52.88

Muriatic acid gas.—hydrogen 5.53+94.47 chlorine.
Sulphuric acid, dry,—oxygen 79.67+20.33 sulphur.
Silicic acid—silica, dry,—oxygen 51.96+48.04 silicon.
Boracic acid—borax, dry,—oxygen 68.81+31.19 boron.

a. The atmosphere, in addition to its constituents as given in the table, contains, besides a small quantity of vapor, from 1 to 3 parts in a thousand of carbonic acid gas, and a trace merely of ammoniacal gas.

b. Anthracite coal, charcoal. plumbago, coke, etc., have no other constituent than carbon; they are combined, to a small extent, with foreign matters, such as iron, silica, sulphur, alumina, etc.

c. The constituents of woods, grains, etc., are given per cent., without regard to foreign matters (metallic) which they contain. In oak, chestnut, and Norway pine, the ashes amount to about 4-10 of 1 per cent., and in ash and maple to 7-10 of 1. In anthracite coals, at an average, they are about 7 per cent.

d. Fibrin, Gelatin, Albumen—proximate animal constituents—nutritious properties of animal matter.

Fibrin is the basis of the muscle (lean meat) of all animals, and is also a large constituent of the blood.

Gelatin exists largely in the skin, cartilages, ligaments, tendons and bones of animals. It also exists in the muscles and the membranes.

Albumen exists in the skin, glands and vessels, and in the serum of the blood. It constitutes nearly the whole of the white of an egg.

The relative quantities by volume of the several gases going to constitute any particular compound, are readily ascertained by help of their respective specific gravities, compared with their relative weights, as given per cent. in the preceding table:—thus, the sp. gr. of hydrogen is .0689, and that of oxygen 1.1025, and 1.1025÷.0689=16; showing the weight of the latter to be 16 times that of the former per equal volumes, or, relatively, as 16 to 1. The per cent. by weight as shown by the table, in which these two gases combine to form water, for instance, is 11.1 and 88.9; or 11.1 of hydrogen and 88.9 of oxygen in 100 of the compound; or as 88.9÷11.1,—as 8 to 1; 16÷8=2; two volumes, therefore, of the lighter gas (hydrogen) combine with one of oxygen to form water. Water, consequently, is a protoxide of hydrogen.

Upon the principle of Atomic Weights—primal quantities, by weight, in which bodies combine, based upon some fixed radix, usually hydrogen as it forms with water, and as 1,—we have, for water,—H^1+O^8=Aq. 9. An atom of hydrogen, therefore, is 1, an atom of oxygen 8, and an atom of water 9.

By the same rule as the preceding, the constituents of atmospheric air are found to be to each other in volume as 4 to 1,—4 volumes of nitrogen and 1 volume of oxygen=atmospheric air. The weight of nitrogen to hydrogen per equal volumes, is 14.14 to 1. Atomically, therefore, oxygen being 8, it is as 7.7 to 1; hence we have N^4+O=36.28, the atomic weight of atmosphere.

The vast condensation of the gases which takes place, in some instances, in forming compounds, may be conceived of, and the process for determining the same exhibited by a single illustration. We will take, for example, water. A single cubic inch of distilled water, at 60°, weighs 252.48 grains. Its weight is to that of dry atmosphere, at the same temperature, as 827.8 to 1. A cubic inch of dry atmosphere, therefore, at that density, weighs .305 of a grain. Hydrogen, we find by the table of Specific Gravities. weighs .0689 as much as atmosphere. and oxygen 1.1025 as much. A cubic inch of hydrogen, therefore, weighs .0689×.305=00. 145 of a grain, and a cubic inch of oxygen 1.0125×.305,=3362625 of 21 grain. The constituents of water by volume are 2 of the first mentio aed gas to 1 of the latter; and .0210145×2+.3362625=.3782915 of a grain =wneight of three cubic inches of the uncondensed compound, ⅓ of which, .1260972 of a grain, is the weight of a volume 1 cubic inch.

As the weight of a given volume of the uncondensed compound, is to the weight of an equal volume of the condensed compound, so are their respective volumes, inversely: then

.1260972 : 252.48 : : 1 : 2002.26, the number of cubic inches of the two

gases condensed into 1 inch to form water; a condensation of 2001 times. Of this volume of gases, $\frac{2}{3}$, or 1334.84 cubic inches, is hydrogen; the remaining third, 667.42 cubic inches, is oxygen.

The foregoing method, though strictly correct, does not exhibit in a general way the most expeditious for solving questions of that nature, the condensation which takes place in the gases on being converted into solids, or dense compounds. It was resorted to, in part, as a means through which to exhibit principles and proportions pertaining thereto.

As before: one cubic inch of water weighs 252.48 grains, 1-9 of which, or 28.05+grains, is hydrogen, and 8-9, or 224.43+grains, is oxygen. The volume of 1 grain of oxygen is 2.97+cubic inches, and the volume of hydrogen is 16 times as much, or 47.58+cubic inches. Therefore $28.05 \times 47.58 = 1334.62$, and $224.43 \times 2.97 = 665.56, = 2001.18$, condensation as before.

PROPERTIES OF THE SIMPLE SUBSTANCES AND SOME OF THEIR COMPOUNDS, NOT GIVEN IN THE FOREGOING.

Bromine,—at common temperatures, a deep reddish-brown volatile liquid; taste, caustic; odor, rank; boils at 116°; congeals at 4°; exists in sea-water, in many salt and mineral springs, and in most marine plants; action upon the animal system very energetic and poisonous—a single drop placed upon the beak of a bird destroys the bird almost instantly. A lighted taper, enveloped in its fumes, burns with a flame green at the base and red at the top; powdered tin or antimony brought in contact is instantly inflamed; potash is exploded with violence.

Chlorine,—a greenish-yellow, dense gas; taste, astringent; odor, pungent and disagreeable; by a pressure of 60 pounds to the square inch is reduced to a liquid, and thence, by a reduction of the temperature below 32°, into a solid. It exists largely in sea-water—is a constituent of common salt, and forms compounds with many minerals; is deleterious, irritating to the lungs, and corrosive; has eminent bleaching properties, and is the greatest disinfecting agent known; a lighted taper immersed in it, burns with a red flame; pulverized antimony is inflamed on coming in contact, so is linen saturated with oil of turpentine; phosphorus is ignited by it, and burns, while immersed, with a pale-green flame; with hydrogen, mixed measure for measure, it is highly explosive and dangerous.

Fluorine,—a gas, similar to chlorine,—exists abundantly in fluor-spar.

Oxygen,—a transparent, colorless, tasteless, inodorous, innoxious gas; supports respiration and combustion, but will not sustain life for any length of time, if breathed in a pure state. It is by far the most abundant substance in existence; constitutes 1-5 of the atmosphere; 8-9 of water; and nearly the whole crust of the earth is oxidized substances. For further combinations and properties, see Table of Elementary Constituents and Chemical Elements.

Iodine,—at common temperatures, a soft, pliable, opaque, bluish-black solid; taste, acrid; odor, pungent and unpleasant; fuses at 225°; boils at 347°; its vapor is of a beautiful violet color; it inflames phosphorus, and is an energetic poison; exists mainly in sea-weeds and sponges.

Hydrogen,—a transparent, colorless, tasteless, inodorous, innoxious gas; if pure, will not support respiration; if mixed with oxygen, produces a profound sleep; exists largely in water; is the basis of most liquids, and is by far the lightest substance known; burns in atmosphere with a pale bluish light; mixed with common air, 1 measure to 3, it is explosive; mixed with oxygen, 2 measures to 1, it is violently so.

Nitrogen, or Azote,—a transparent, colorless, tasteless, inodorous gas; will not support respiration or combustion, if pure; exists largely as a con-

stituent of the atmosphere—in animals, and in fungous plants; is evolved from some hot springs; in connection with some bodies, appear combustible.

Carbon,—the diamond is the only pure carbon in existence; pure carbon cannot be formed by art; charcoal is 97 per cent. carbon; plumbago, 95; anthracite, 93. Carbon is supposed by some to be the hardest substance in nature. A piece of charcoal will scratch glass; but it is doubtful if this is not due to the form of its crystals, rather than to the first mentioned quality. It is doubtless the most durable. For combinations, etc., see table.

Boron,—a tasteless, inodorous, dark olive-colored solid.

Silicon,—a tasteless, inodorous solid, of a dark-brown color; exists largely in soils, quartz, flint, rock crystal, etc.; burns readily in air, vividly in oxygen gas; explodes with soda, potassa, baryta.

Phosphorus,—a transparent, nearly colorless solid, of a wax-like texture; fushes at 108°, and at 550° is converted into a vapor; exists mainly in bones—most abundant in those of man—is poisonous; at common temperatures it is luminous in the dark, and by friction is instantly ignited, burning with an intense, hot, white flame; must be kept immersed in water.

Selenium,—a tasteless, inodorous, opaque, brittle, lead colored solid, in powder, a deep red color; becomes fluid at 216°, boils at 650°; vapor, a deep yellow; exists but sparingly, mainly in combination with volcanic matter; is found in small quantities combined with the ores of lead, silver, copper, mercury.

Ammoniacal gas,—$N+H^3$; transparent, colorless, highly pungent and stimulating; alkaline; is converted into a transparent liquid by a pressure of 6.5 atmosphere, at 50°; does not support respiration; is inflammable.

Carbonic acid gas,—$C+O^2$; transparent, colorless, inodorous, dense; is converted into a liquid by a pressure of 36 atmospheres; exists extensively in nature, in mines, deep wells, pits; is evolved from the earth, from ordinary combustion, especially from the combustion of charcoal, and from many mineral springs; is expired by man and animal; forms 44 per cent. of the carbonate of lime called marble; the brisk, sparkling appearance of soda-water, and most mineral waters, is due to its presence. It is neither a combustible nor a supporter of combustion; and, when mixed with the atmosphere to an extent in which a candle will not burn, is destructive of life. Being heavier than atmosphere, it may be drawn up from wells in large open buckets; or it may be expelled by exploding gunpowder near the bottom. Large quantities of water thrown in will absorb it.

The above gas is expired by man to the extent of 1632 cubic inches per hour; it is generated by the burning of a wax candle to the extent of 800 cubic inches per hour; and, by burning of "camphene" (in the production of light equal to that afforded by 1 wax candle), to the extent of 875 cubic inches per hour. Two burning candles, therefore, vitiate the air to about the same extent as one person.

Carbonic oxide gas,—$C+O$; transparent, colorless, insipid; odor, offensive; does not support combustion; an animal confined in it soon dies; is highly inflammable, burning with a pale blue flame; mixed with oxygen, 1 to 2, is explosive—with atmosphere, even in small quantity, is productive of giddiness and fainting.

Carbureted hydrogen gas,—$C+H^2$; transparent, colorless, tasteless, nearly inodorous; exists in marshes and stagnant pools—is there formed by the decomposition of vegetable matter; extinguishes all burning bodies, but at the same time is itself highly combustible, burning with a bright but yellowish flame; it is destructive to life, if respired.

Cyanogen—Bicarburet of Nitrogen—a *gas*,—$N+C^2$; transparent, colorless, highly pungent and irritating; under a pressure of 3.6 atmospheres, becomes a limpid liquid; burns with a beautiful purple flame.

Hydrochloric acid gas—Muriatic acid gas,—$H+Cl$. (chlorine); transparent, colorless, pungent, acrid, suffocating; strong acid taste.

Nitrous oxide gas—Protoxide of Nitrogen, "*laughing gas*."—$N+O$; transparent, colorless, inodorous; taste sweetish; powerful stimulant, when breathed, exciting both to mental and muscular action; can support respiration but from 3 to 4 minutes; is often pernicious in its effects.

Nitric oxide gas—Binoxide of Nitrogen.—$N+O^2$; transparent, colorless; wholly irrespirable; lighted charcoal and phosphorus burn in it with increased brilliancy.

Olefiant gas—Bicarbureted hydrogen gas—"*coal gas*,"—C^2+H^2; transparent, colorless, tasteless, nearly inodorous, when pure; does not support respiration or combustion; a lighted taper immersed in it is immediately extinguished. It burns with a strong, clear, white light; mixed with oxygen, in the proportion of 1 volume to 3, it is highly explosive and dangerous.

Phosphureted hydrogen gas.—$P+H^3$; colorless; odor, highly offensive; taste, bitter; exists in the vicinity of swamps, marshes, and grave-yards; is formed by the decomposition of bones, mainly; is highly inflammable; takes fire spontaneously on coming in contact with the atmosphere; mixed with pure oxygen, it explodes. It is the veritable "Will o' the Wisp."

Sulphureted hydrogen gas—Hydrosulphuric acid gas—$S+H$; transparent, colorless; taste, exceeding nauseous; odor, offensive and disgusting; is furnished by the sulphurets of the metals in general, also by filthy sewers and putrescent eggs. It is very destructive to life; placed on the skin of animals, it proves fatal. It burns with a pale blue flame, and, mixed with pure oxygen, it is explosive.

Hydrocyanic acid—Prussic acid—$N+C^2+H$; a colorless, limpid, highly volatile liquid; odor, strong, but agreeable, similar to that of peach blossoms; it boils at 79° and congeals at 0; exists in laurel, the bitter almond, peach and peach kernel. It is a most virulent poison, a drop placed upon a man's arm caused death in a few minutes. A cat, or dog, punctured in the tongue with a needle fresh dipped in it, is almost instantly deprived of life.

Hydrofluoric acid.—$F+H$; a colorless liquid, in well stopped lead or silver bottles, at any temperature between 32° and 59°. It is obtained by the action of sulphuric acid on fluor-spar. It readily acts upon and is used for etching on glass. It is the most destructive to animal matter of any known substance.

Nitrohydrochloric acid—"*aqua regia*,"—(1 part nitric acid and 4 parts muriatic acid, by measure); a solvent for gold. The best solvent for gold is a solution of sal ammoniac in nitric acid.

Nitrosulphuric acid,—(1 part nitric acid and 10 parts sulphuric acid, by measure); a solvent for silver; scarcely acts upon gold, iron, copper, or lead, unless diluted with water; is used for separating the silver from old plated ware, etc. The best solvent for silver, and one which will not act in the least upon gold, copper, iron, or lead, is a solution of 1 part of nitre in 10 parts of concentrated sulphuric acid, by weight, heated 160°. This mixture will dissolve about 1-6 its weight of silver. The silver may be recovered by adding common salt to the solution, and the chloride decomposed by the carbonate of soda.

Selenic acid.—$Se+O^3$; obtained by fusing nitrate of potassa with selenium, a solvent for gold, iron, copper and zinc.

Silicic acid.—(Silica—silex; base Silicon)—$Si+O^3$; exists largely in sand. Common glass is fused sand and protoxide of potassium (carbonate of potassa—potash) in the proportion of 1 part by weight of the former to 3 of the latter.

Manganese, compounded with oxygen, in different proportions, imparts the various colors and tints given to fancy glass ware, now so generally in vogue.

THE EFFICIENCY OF FLUIDS IN VAPOR ENGINES.

The following article was taken from the Boston Journal of Commerce, Vol. 25, No. 10. Not having the necessary room the cuts with the accompanying explanations were omitted:

In Van Nostrand's Engineering Magazine, for November, 1884, is an able paper upon the Efficiency of Fluid in Vapor Engines, by H. L. Gantt, A. B., M. E., and D. H. Maury, Jr., M. E. At all times interesting, this subject has gained an especial interest in the various attempts which have been made to gain an advantage over steam by the use of the vapor of the more volatile fluids in the cylinders of heat engines. Rankine, Clausius, and others have proved that the amount of heat transformed into work does not depend upon the fluid which is the conveyer of that heat, but simply upon the limits of temperature between which the fluid is worked. It follows, theoretically, that all fluids are of equal efficiency in transforming it into work. It does not follow, however, that all fluids are equally valuable as the working fluid of an engine, for there are other considerations besides efficiency to be taken into account in making choice of a working fluid. The task undertaken by the authors was that of choosing the best working fluid from among the following liquids: Water, alcohol, ether, bisulphide of carbon, and chloroform, considering them theoretically, under various conditions.

Case 1 is devoted to a discussion of Carnot's cycle, in general, and as applied to the vapors in question, with the object of showing that while the efficiency of a fluid is the same in each case, that of the engine may be different, and in general will be, since its efficiency will be less as the size of the engine required to produce a given power is larger. Carnot's cycle consists of an isothermal expansion, an adiabatic expansion, an isothermal compression, and an adiabatic compression up to the original temperature. A certain number of units of heat are taken as a starting point, and this amount of heat is supposed to be worked in the cycle of Carnot, between an equal limit of temperature by just so much of each of the fluids as will be evaporated by it, and it is shown that while neither the work of expansion nor that of compression in any case is equal to a corresponding quantity, the difference of the effective work is equal in all cases.

The results obtained from the calculation of Case 1 are as follows:

Vapors.	Work of Expansion	Work of Compres'n.	Effective Work.	Heat used.	Efficiency.
Water	274.767	83.408	191.359	1.038.300	18.43 %
Alcohol	331.22	139.863	191.359	1.038.300	18.43 %
Ether	466.740	275.381	191.359	1.038.300	18.43 %
Bisulphide of carbon	354.120	162.761	191.359	1.038.300	18.43 %
Chloroform	347.474	156.115	191,359	1.038.300	18.43 %

The object of Case 2 is to determine which of the fluids, water, alcohol, ether, bisulphide of carbon, or chloroform, would be most suitable as the working fluid of an engine if worked as a saturated vapor in a non-conducting cylinder, between the limits of pressure usually employed in a steam engine. The limits of pressure assumed are 6214.6 millimeters of mercury, corresponding with a pressure of about 122 pounds absolute to the square inch for the higher and 517.9 millimeters of mercury corresponding with a pressure of about 10 pounds absolute to the square inch for the lower. The corresponding temperature for each of the fluids is given below:—

Vapors.	Initial Tem.	Final Tem.
Water	341	194
Alcohol	291	156
Ether	230	76
Bisulphide of Carbon	266	95
Chloroform	285	120

It has been found in steam engine practice that it is not economical to expand down to the back pressure, the best results having been obtained when there is a difference between final and back pressure of from seven to ten pounds on the square inch. It is probable that the best practical results in the cases of the other vapors would be obtained by producing a similar difference between the final and back pressure. This assumption suggests a modification of Case 2, which is given as Case 3. The results obtained from the calculation of Case 2 are as follows:—

Vapors.	Work.	Heat.	Efficiency—per cent.	Relative size of cylinder to produce the same power.	Pounds used per horse power per hour.
Water	54.829	272,528	20.12	1.	11.44
Alcohol	54.196	300,088	18.06	1.071	30.48
Ether	31,058	324,206	13.85	2.275	89.24
Bisulphide of carbon	35.545	179.973	19.75	1.480	78.15
Chloroform	47.609	232.685	20.46	1.264	90.30

In Case 3, the same initial pressure is taken as before, but the final pressure has been determined by adding a nearly constant quantity to the back pressure, which latter pressure is determined by the temperature of the condenser, 40° C. The results of this method are as follows:—

Vapors.	Work.	Heat.	Efficiency—per cent.	Relative size of cylinder to produce the same power.
Water	54.829	1,030,639	20.12	1.
Alcohol	53,786	1,465,207	17.92	1.035
Ether	33.357	1,094,722	14.88	.845
Bisulphide of carbon	33,858	878,729	18.53	.756
Chloroform	44.894	1,136,084	19.29	.947

In Cases 2 and 3 has been considered the behavior of the several vapors in question when used as working fluids between the limits of pressure common in the modern steam engine. In Cases 4 and 5 their behavior when worked between the limits of temperature used in the steam engine is considered. The temperature corresponding with the pressure assumed in the two preceding cases are retained in Cases 4 and 5, namely, 172° C. to 90° C. A diagram plotted under these circumstances will show that the fluids have been considered at the same temperature producing diagrams in which the initial pressure is widely different. The results obtained are as follows:

Vapors.	Work.	Heat.	Efficiency—per cent.	Pounds used per horse power per hour.	Relative size of cylinder to produce the same power.
Water	54,829	272,528	20.12	11.45	1.
Alcohol	107.543	572,904	18.14	28.94	.488
Ether	153.980	910.954	16.90	63.10	.232
Bisulphide of carbon	73.911	368.310	20.07	75.87	.314
Chloroform	77.114	410.058	18.81	92.72	.396

Case 5 bears the same relation to Case 4 that Case 3 bears to 2. In the preceding case the most favorable practical conditions are not assumed for the working of either of the fluids with the exception of water. Hence in Case 5 the same values were assumed for back pressure as were taken in Case 3, the following table showing the results obtained:

Vapors.	Work.	Heat.	Efficiency — per cent.	Pounds used per horse power per hour.	Relative size of cylinder to produce the same power.
Water	54.829	272,528	20.12	11.44	1.
Alcohol	127,592	572,904	21.52	24.40	.853
Ether	200,506	910.954	22.23	48.02	.535
Bisulphide of carbon	87.758	368,310	23.83	63.88	.550
Chloroform	94,793	410.058	23.12	75.42	.861

From their calculations, the authors have deduced the following conclusions:

From Case 1, which is simply an illustration of a well-known law of thermodynamics, it may be seen that the theoretical effective work obtainable from a quantity of heat is when Carnot's cycle and the same limits of temperature are employed, independent of the working fluid. At the same time, however, the component parts of the total work may vary very much, as is illustrated by the results as given of Case 1. On comparing the efficiencies of the non-aqueous vapors in Case 2 with the same quantities in Case 3, we see that in every case except that of ether, the figures are larger in the former than in the latter case. It would, therefore, seem at first sight that the methods we have taken of increasing the efficiency by reducing the ratio of expansion must fail. It must be remembered, how-

ever, that while in the ideal case expansion down to the back pressure is most efficient, there are certain practical considerations, such as condensation in the cylinder and friction of engine, which make a more limited ratio of expansion best. It is to this best ratio that we have tried to approximate in Case 3, and hence the performance of engines built for working these fluids would agree more nearly with the results of this case than with those of Case 2. It is for this reason that we consider the results in Case 3 of more practical value than those of the case preceding it, and it may be seen that, if we limit maximum pressure to that employed in the steam engine, steam is the most efficient fluid we can use. The relative size of cylinder necessary to produce the same power, which is shown in the results as given by Case 3, is smaller for steam than it is for the non-aqueous vapors, when all have the same initial pressure. Case 5 resembles Case 3, in having the same final pressure, but differs in having higher initial pressure, involving higher initial temperature, and consequently greater range of temperature causes such an increase of efficiency of the non-aqueous vapors as to put them all above that of water, and to cause some doubt as to which would be the most efficient working fluid, judged thermodynamically only. As the most convenient method of deciding the question just raised, we may compare all the vapors with that of water, showing their advantages and disadvantages. The vapor alcohol gives us 1.4 per cent. more efficiency than steam, and requires a cylinder whose volume is only .853 of that of the steam cylinder to produce the same power. The disadvantages of alcohol are the high tension of the vapor, the great danger which arises from the ready inflammability of the hot alcohol, and its cost. The use of ether would give us a greater gain in efficiency, 2.11 per cent., and would require a still smaller cylinder, .535 of that of steam, but is open to the same objections as alcohol, and in a more marked degree. The vapor of bisulphide of carbon gives a gain in efficiency of 3.71 per cent., and demands a cylinder .55 of that of steam. It is, however, not only open to all the objections that have been stated against alcohol and ether, but it has two which are peculiar to it, viz., its intensely disagreeable odor and its power of rapidly corroding iron which comes alternately in contact with it and the air. The vapor of chloroform, which gives a gain of 3 per cent. efficiency and requires a cylinder of .761, the volume of that of steam, is not open to the objection of inflammability, but it has so high a cost that it is probably impossible that it can ever be used economically in competition with steam. All the apparent disadvantages of the non-aqueous vapors may be gained in the steam engine by an increase of initial pressure, and as the tendency of modern practice is in that direction, it seems certain that none of the non-aqueous vapors will ever successfully compete with steam.

NEW STANDARD TIME.

To change to the New Standard Time, apply a plus or minus correction, which is to be found by subtracting the adopted "division" or "standard" longitude of the place from its Greenwich longitude reduced to time.

For example: the "division" longitude adopted for Boston is 75°, or 5 hours; which subtracted from its actual longitude of 71° 4′, or 4h. 44m., gives a correction of (—3° 56′.) 16 minutes to be subtracted from the printed values for Boston.

Again: the "division" longitude of Omaha is 6 hours, which subtracted from Omaha's longitude of 6h. 24m., leaves a correction of 24 minutes to be added, in order to change to Omaha's standard.

Correction for the Following Cities.

Eastern Standard.—75° Lon.	Minutes.	Central Standard. —90° Lon.	Minutes.
Bangor, Me	— 25	Cleveland, Ohio	— 33
Augusta, Me	— 21	Columbus, Ohio	— 28
Portland, Me	— 19	Detroit, Mich	— 28
Boston, Mass	— 16	Toledo, Ohio	— 26
Newport, R. I	— 15	Dayton, Ohio	— 23
Providence, R. I	— 14	Cincinnati, Ohio	— 22
Concord, N. H	— 14	Louisville, Ky	— 18
New London, Ct	— 11	Indianapolis, Ind	— 16
Springfield, Mass	— 10	Chicago, Ill	— 10
Montpelier, Vt	— 10	Milwaukee, Wis	— 8
Hartford, Ct	— 9	Springfield, Ill	— 2
Montreal, Que	— 6	Memphis, Tenn	— 0
Albany, N. Y	— 5	New Orleans, La	— 0
New York, N. Y	— 4	St. Louis, Mo	+ 1
Utica, N. Y	+ 1	Rock Island, Ill	+ 3
Philadelphia, Pa	+ 1	Dubuque, Iowa	+ 3
Syracuse, N. Y	+ 5	Burlington, Iowa	+ 5
Baltimore, Md	+ 6	St. Paul, Minn	+ 12
Washington, D. C	+ 8	Des Moines, Iowa	+ 14
Rochester, N. Y	+ 11	Kansas City, Mo	+ 18
Buffalo, N. Y	+ 16	Galveston, Tex	+ 19
Pittsburg, Pa	+ 20	Omaha, Neb	+ 24
Mountain Standard.—105° Lon.		**Pacific Standard.—120° Lon.**	
Denver, Col	0	Sacramento, Cal	+ 6
Salt Lake City, Utah	+ 28	San Francisco, Cal	+ 10

HYDROSTATICS.

All fluids, at rest, press equally in every direction. The pressure exerted by them, therefore, can never be so little as their weight, and may, under circumstances, be to almost any conceivable extent greater. The downward pressure exerted by a fluid is its weight, and its weight is as the quantity; but the lateral pressure exerted is in a measure independent of quantity, being dependent upon depth, or vertical height.

Any given area, in any given section of a containing vessel, is pressed equal to the weight of a column of the fluid whose base is equal to the area pressed, and whose height is equal to the distance of the centre of gravity of that area, below the surface of the fluid; this is the case whether the sustaining surface be horizontal, or vertical, or oblique.

The bottom of a containing vessel, therefore, whatever be its shape, sustains a pressure equal to the weight of the superincumbent fluid, or equal to the weight of a column of the fluid whose base is equal to the area of the bottom, and height equal to the distance from the bottom to the surface—equal to the area of the bottom, multiplied by the depth of the liquid multiplied by its weight, in like terms of measurement.

And each side of the containing vessel, whatever number of sides there be, sustains a pressure equal to the area of that side multiplied by half the

depth of the liquid, multiplied by its weight, in the same terms of measurement.

Thus, a rectangular vessel, whose sides and bottom are equal, and each two feet square, has a capacity of 8 cubic feet; it will hold, consequently, 8 cubic feet of fresh water, one cubic foot of which weighs $62\frac{1}{2}$ lbs. It will hold, therefore, $62\frac{1}{2} \times 8 = 500$ lbs. of water. Now, if we suppose this vessel filled with water, we have, according to the foregoing, a pressure on the bottom of $2 \times 2 \times 2 \times 62.5 = 500$ lbs.; a pressure exactly equal to the weight of all the fluid. And we have, upon each of the four sides, a pressure of $2 \times 2 \times 1 \times 62.5 = 250$ lbs.; a lateral pressure, therefore, equal to $250 \times 4 = 1000$ lbs., equal to twice the pressure on the bottom, and showing the entire pressure exerted to be 300 per cent. greater than the weight of the water employed.

Again: if we suppose the above vessel contracted, laterally, to the extent that its sides are but 3 inches, or $\frac{1}{4}$ of a foot apart, throughout, and that its length is so extended that it still holds the 8 cubic feet of water, then we have, upon the bottom, whose area is only 9 square inches, a pressure of $.25 \times .25 \times 128 \times 62.5 = 500$ lbs. as before; and upon each side we have a pressure of $.25 \times 128 \times \frac{128}{2} \times 62.5 = 128000$ lbs.; making in all a pressure of $128000 \times 4 + 500$,—the enormous pressure of 512500lbs., and that too, exerted by 8 cubic feet or 500 lbs. of water. It is easy to see that the same principles hold good under any extent of lateral area.

EXAMPLE:—A sluice or flood-gate is 3 feet by $2\frac{1}{2}$, and its centre is 12 feet below the surface of the water; what pressure does the water exert upon it?

$$3 \times 2.5 \times 12 \times 62.5 = 5625 \text{ lbs. } \textit{Ans.}$$

EXAMPLE.—A dam, that presents a perpendicular resistance to a stream, is 40 feet long and 15 feet high; the water is level with its top; what pressure does the dam sustain, supposing the water at rest, and what is the mean pressure against it per square foot?

$40 \times 15 \times \frac{15}{2} \times 62.5 = 281250$ lbs., pressure against the dam; and

$281250 \div 40 \times 15 = 468\frac{3}{4}$ lbs., mean pressure per sq. foot. *Ans.*

EXAMPLE.—The same stream, the same length of dam, and the same vertical height as the preceding, and the dam sloping into the stream against the current, 30 feet from its base; required the pressure against the dam, and the average pressure per square foot.

$$\left.\begin{array}{l} 40 \times 15 \times 7.5 \times 62.5 = 281250 \text{ lbs., pressure as before.} \\ \sqrt{15^2 + 30^2} = 33.541 \text{ feet, slant height of dam; and} \\ 281250 \div 40 \times 33.541 = 209.63 \text{ lbs. av'g pres. per sq. foot.} \end{array}\right\} \textit{Ans.}$$

For calculating the horse power of a given quantity of water in a given time, 7,000,000 gallons of water passing through the turbine in 60 hours.

RULE.—Multiply the fall in feet by .3682; the product is the horse power net. This is unit. If there is more or less water, or more or less time, the horse power developed will be more or less in direct proportion. —[From testimony of J. B. Francis, C. E.

Another rule: 8.8 cubic feet of water per second falling 1 foot, is equal to one horse power.—[From testimony of C. Hershell, C. E.

HYDRAULICS.

The established law for the velocity of all bodies falling from rest is given under Gravitation, viz., that $\sqrt{\text{height} \times 64.66}$, or $\sqrt{\text{height}} \times 8.04 =$

velocity per second, or velocity in one second of time, the velocity and height both being in the same denomination of measure. And from what has been said concerning pressure, under Hydrostatics, it is evident that the same law will cause water or other fluid to flow through an opening in the side of the reservoir, or dam, with the same velocity that a body would attain falling perpendicularly through a space equal to that between the surface of the water and the centre of the opening alluded to; and that, consequently, theoretically, the quantity thus discharged, in any given time, will be equal to the product of the velocity and area of the opening, multiplied by that time.

The theoretical law, however, last adduced, under ordinary circumstances, does not apply. And the quantity discharged, owing to the contraction of the fluid vein, caused by the friction of the particles against the sides of the opening, falls short of that theoretically due. The only instance known in which the full force of the law may be obtained, is where the discharge is made to issue through a straight tube whose form is the frustum of a cone, its length being half the diameter of the aperture, and the diameter of the receiving end to that of the discharging end as 5 to 8; when a fluid is allowed to pass through such an opening, no contraction of the vein takes place.

From various carefully conducted experiments by M. Morin, Eytelwein, Bossut, and others, the following practical rules for ascertaining the quantity discharged through different openings, and under different heads, are derived:—

1. When the issue is through a circular opening, its upper vertical point as high as the surface of the fluid, estimate the height or head from the centre of the opening to the surface of the fluid, and use 5.4, instead of 8.04, as the coefficient of quantity.

2. When the opening is circular, and under a head equal to its diameter, estimate the head as in the preceding, and use 8 as the coefficient.

3. When the issue is through a rectangular orifice, two or more feet beneath the surface, estimate the head from the centre of the orifice to the surface of the water, and use 5.1 as the coefficient.

4. When the discharge is from a rectangular opening, extending as high as the surface of the fluid, estimate the head from the bottom of the opening to the surface of the water, and use 3.4 as the coefficient. This rule applies to water flowing over a dam, or from a notch or slit cut in its side, etc.

It may be proper to add, that if the orifice is small and under considerable head, the quantity discharged, relatively, will be slightly, less than would be discharged if the opening were nearer the surface.

From the foregoing we obtain the following

General Rule.

Multiply the square root of the height, or head (as estimated in the foregoing), in feet, by the coefficient of quantity given as pertaining thereto, and the quotient will be the coefficient velocity in feet per second of the discharge: which, multiplied by the area of the opening in feet, gives the quantity in cubic feet discharged in a single second, or in each second of time.

Example.—A rectangular opening in the side of a dam is 6 feet long and 8 inches deep, and the distance from the centre of the opening to the surface of the water is 4 feet; required the quantity of water discharged in each second of time.

$\sqrt{4}=2\times5.1\times6\times\frac{2}{3}=40.8$ cubic feet. *Ans.*

EXAMPLE.—A dam is 60 feet long, and the water flows over its entire ength 6 inches, or ½ foot deep; what quantity flows over per second?

$\sqrt{.50}$*=.7071×3.4×60×.5=72¼ cubic feet. *Ans.*

THE HYDRAULIC, OR HYDROSTATIC PRESS.

This is a machine by which a small force may be made to exert a great pressure. Its construction may be understood by stating that it has a large, strong cylinder, fitted with a plunger securely packed where it works into the cylinder. At the outer end, attached to the plunger, is a heavy plate working between the tie rods, which secures the top to the bottom of the press, upon which rests the large cylinder. At the bottom of this cylinder is a small pipe, which conveys the fluid from the small force pump which produces the power. There is also a large faucet or valve in the large cylinder to relieve it quickly when necessary.

The pump may be operated by hand lever or power. A safety valve may be attached to relieve excessive pressure; also a gauge to note the pressure. The compression obtained by the press, is the proportion the pump and pipe bears to the area of the cylinder, with the power exerted.

The weight of a man's hand might thus be made to lift many thousand tons, the only limit being the strength of the machine.

THE HYDRAULIC RAM.

The ram can be applied to convey water a distance of from 100 to 200 rods, and to elevations of from 100 to 200 feet.

A fall of 10 feet from the spring or brook to the ram is sufficient to force the water to any elevation not over 150 feet above the ram, and in distance not over 150 rods from it.

Although the same fall will raise water to a much greater elevation, and force it to a greater distance, yet the quantity will diminish as the height and distance are increased.

When a sufficient quantity of water is raised by an adequate fall, the fall should not be increased, as by so doing the strain upon the ram is unnecessarily increased, and its durability lessened.

The proportion which the height to which the water is raised, and the quantity raised, bear to the fall and to the volume of the spring or stream, is about five times the height of the fall, and 1-7 of the volume of the stream forced a distance of 50 rods—allowing for the friction in both the supply and discharging pipes.

Thus, if the ram be placed under a fall of 5 feet, for every 7 gallons drawn from the spring, 1 gallon may be raised 25 feet, or ½ a gallon 50 feet, and forced a distance of 50 rods. If the fall be 10 feet, it will raise one gallon 50 feet, or ½ a gallon 100 feet, for every 7 gallons discharged by the stream. If the fall be 10 feet, and the volume of the stream be doubled, it will raise 1 gallon 100 feet, and so on in the same ratio.

THE WEATHER.

The following table, and the accompanying remarks, originally formedl by Dr. Herschel, and approved with some alterations by the experienced Dr. Adam Clarke, are the result of many years' close observation; the whole being on a due consideration of the attraction of the sun and moon, in their several positions, respecting the earth, and will, by inspection, show the observer what kind of weather will most probably follow the

*The decimal .50 is the same value as .5, =½, but it will be recollected that to obtain the root of a decimal full periods must be used.

entrance of the moon into any of its quarters—so probably, indeed, that it has seldom been found to fail.

TABLE

For Telling the Weather through all the Lunations of Each Year Forever.

Moon.	Time of Change.	In Summer.	In Winter.
If the new moon, the first quarter, full moon, or last quarter, happens	Between midnight and 2 A. M.,	Fair.	Hard frost, unless the wind be S. or W.
	—2 and 4 morning,	Cold, with frequent showers	Snow and stormy.
	—4 and 6 "	Rain.	Rain.
	—6 and 8 "	Wind and rain.	Stormy.
	—8 and 10 "	Changeable.	Cold rain.if wind be W. snow if E.
	—10 and 12 "	Frequent showers	Cold and high wind.
	At 12 o'clock noon, and 2 P. M.,	Very rainy.	Snow or rain.
	B'tween 2 and 4 P.M.	Changeable.	Fair and mild.
	— 4 and 6 "	Fair.	Fair.
	— 6 and 8 "	F. if wind N.W. Rain if S.or S.W.	Fair and frosty, if wind N. or N. E. R'n or s'w,if S.or S.W.
	— 8 and 10 "	Do.	Do.
	— 10 and midnight	Fair.	Fair and frosty.

Observations.

1. The nearer the time of the moon's change, first quarter, full, or last quarter are to midnight, the fairer will the weather be during the seven days following.

2. The space for this calculation occupies from ten at night till two next morning.

3. The nearer to mid-day or noon the phases of the moon happen, the more foul or wet weather may be expected during the next seven days.

4. The space of this calculation occupies from ten in the forenoon to two in the afternoon. These observations refer principally to the summer, though they affect spring and autumn nearly in the same ratio.

To compute elevation by boiling point of water.—At sea level water boils at 212° F., for each degree F. less at which water boils, estimate the elevation at 550 feet.

AVERAGE TEMPERATURE AND FALL OF RAIN.

From the following table it will be perceived that Astoria, on the Pacific coast, and Fort Ripley in the interior, are ina bout the same latitude. Astoria, though 650 mile north of Monterey, is only three degrees colder. Fort Ripley is 15 degrees colder than St. Louis, although it is only about 500 miles further north.

San Francisco, St. Louis, and Fort Monroe, are in about the same latitude. The difference between the mean summer and winter temperature

of San Francisco is less than seven degrees; of St. Louis, nearly 44 degrees; and of Fort Monroe, 36 degrees. Eastport is two degrees south of Astoria, but is nine degrees colder.

TABLE, SHOWING THE AVERAGE TEMPERATURE OF THE FOUR SEASONS AT POINTS ON THE PACIFIC AND ATLANTIC COASTS, AND THE INTERIOR OF THIS CONTINENT.

	Temperature.					
	Latitude.	Spring.	Summer.	Autumn.	Winter.	Year.
PACIFIC COAST.						
Montery................	36°36′	53°.99	58°.64	57°.29	51°.22	55°.29
San Francisco..........	37 48′	54 .41	57 .33	56 .83	50 .86	54 .88
Astoria................	46 11′	51 .16	61 .58	53 .76	42 .43	52 .23
INTERIOR.						
St. Louis Arsenal.......	38°40′	54 .15	76 .19	55 .44	32 .27	54 .51
Chicago................	41 52′	44 .90	67 .33	48 .85	25 .90	46 .75
Fort Ripley............	46 19′	39 .33	64 .94	42 .91	10 .01	39 .30
ATLANTIC COAST.						
Fort Monroe, nr. Norfolk	37°	56 .87	76 .57	61 .68	40 .45	58 .89
Fort Columbus, N. Y. H.	40 42′	48 .74	72 .10	54 .55	31 .38	51 .69
Fort Sullivan, Eastport..	44 15′	40 .15	60 .50	47 .52	23 .90	43 .02

TABLE,

SHOWING THE PLANETS, COMPARATIVE SIZE, ETC., IN THE SOLAR SYSTEM.

Names.	Mean Diameter.	Mean distance from the Sun.	Revolution around the Sun.	Revolution on axis.	Velocity pr. minute in orbit.	Size — the Earth be'g 1.	Density:— Earth be'g 1.	Light:— Earth be'g 1.
	Miles	Miles.	yr. dys	d. h. m.	Miles			
The Sun............	883,246	....	... .	25 9 59	....	1,412,921.100	0.252	infin.
Mercury...........	3,224	36,814,000	... 88	1 0 5	1,827	0.053	1.120	6.680
Venus..............	7,687	68,787,000	... 224	.. 23 21	1,338	0.909	0.923	1.911
The Earth..........	7,912	95,103,000	1 ...	.. 23 56	1,138	1.000	1.000	1.000
The Moon...........	2,180	95,103,000	1 ...	27 7 43	38	0.020	0.615	1.000
Mars...............	4,189	144,908,000	1 321	1 0 37	921	0.125	0.948	0.431
Jupiter............	89,170	494,797,000	11 215	.. 9 56	496	1,456.000	0.238	0.037
Saturn.............	79,042	907,162,000	29 167	. 10 29	368	771.000	0.138	0.011
Uranus.............	35,112	1,824,290,000	84 6	1 13 33	259	80.000	0.242	0.003
Neptune............	41,500	2,854,000.009	164 226	.. .. ..	208	143.000	0.140	0.001

FRACTIONS—DECIMALS.

A fraction is one or more parts of a unit, and is expressed by fractional characters, thus, $\frac{1}{2}$, $\frac{1}{4}$, $\frac{3}{4}$; or by decimals, thus, .5, .25, .75.

When expressed by fractional characters, the upper figure is called the *numerator*, because it numbers or gives value to the fraction, by showing how many parts of the whole number into which the unit is divided are taken; and the lower figure is called the *denominator*, because it names the number of parts into which the unit is divided. Thus, $\frac{3}{8}$ means that the unit is divided into 8 parts, and that 3 out of the 8 are taken, etc.

When expressed by a decimal, the decimal number shows that so many parts of the unit are taken, the unit itself being impliedly divided

into as many parts as will correspond with the decimal number, and still retain its ratio to it. Thus, .5 means $\frac{5}{10}$, .25 means $\frac{25}{100}$, .125 means $\frac{125}{1000}$, etc., etc.

To reduce fractions to decimals.

Divide the numerator by the denominator, adding ciphers as required.

EXAMPLE.—What are the decimals of $\frac{1}{2}$, $\frac{3}{4}$, $\frac{7}{8}$?

SOLUTION.—$10 \div 2 = .5$, $300 \div 4 = .75$, $7000 \div 8 = .875$. *Ans.*

To add decimals.

Add as in common addition, setting the whole numbers or integers directly under each other from the decimal point to the left, and the decimals from the decimal point to the right, as in the following example:—

$$\begin{array}{l} 12.75 \\ 24.027 \\ 14.5 \\ 16.1278 \\ \hline 67.4048 \end{array}$$

To subtract decimals.

Set the whole numbers and decimals under each other, as directed above, and proceed as in common subtraction, as in the following example:

$$\begin{array}{r} 75.15 \\ 28.875 \\ \hline 46.275 \end{array}$$

To multiply decimals.

Set the figures and multiply as in common multiplication, and point off in the product as many decimals as there are decimal places in the multiplier and multiplicand, as in the following example:

$$\begin{array}{r} 23.25 \\ 22.15 \\ \hline 11625 \\ 2325 \\ 4650 \\ 4650 \\ \hline 514.9875 \end{array}$$

To divide decimals.

Proceed as in common division, and point off to the right in the quotient as many decimals as the decimal places in the dividend exceed the decimal places in the divisor, as in the following example:

$$\begin{array}{l} 2.48)129.952(52.4 \\ \quad\;\; 124\ 0 \\ \quad\;\; \overline{5\ 95} \\ \quad\;\; 4\ 96 \\ \quad\;\; \overline{9\ 92} \\ \quad\;\; 9\ 92 \\ \quad\;\; \overline{} \end{array}$$

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When Petroleum is used, the residue (80%) is a superior Lubricating Oil, thus obtained without additional cost.

☞See cut on opposite page. A, boiler; B, steam trap; C, steam receiver; D, steam pipe to receiver; E, steam pipe to engine; F, engine cylinder; G, exhaust pipe; H, oil tank; I, oil receiver; J, sight feed reservoir; i^1 and j^1, valves in pipe to and from sight feed; P, glass guage; j_2, water pressure pipe, which may connect with steam pipe and carried high enough to produce sufficient pressure, or may be connected with tank or street main where pressure will permit; j_3, regulating valve; Q, steam trap; M, condense water and oil pipe; O, water and oil tank; R, float for water discharge; S, float for oil discharge; R_1, pipe and valve for water discharge; S_2, pipe and valve for oil discharge; r, r^1, r_2, shives and lines connecting float with water discharge valve; s, s^1, s_2, shive and line connecting float with oil discharge valve; O, O1, shive brackets; O3, stand to support oil float.

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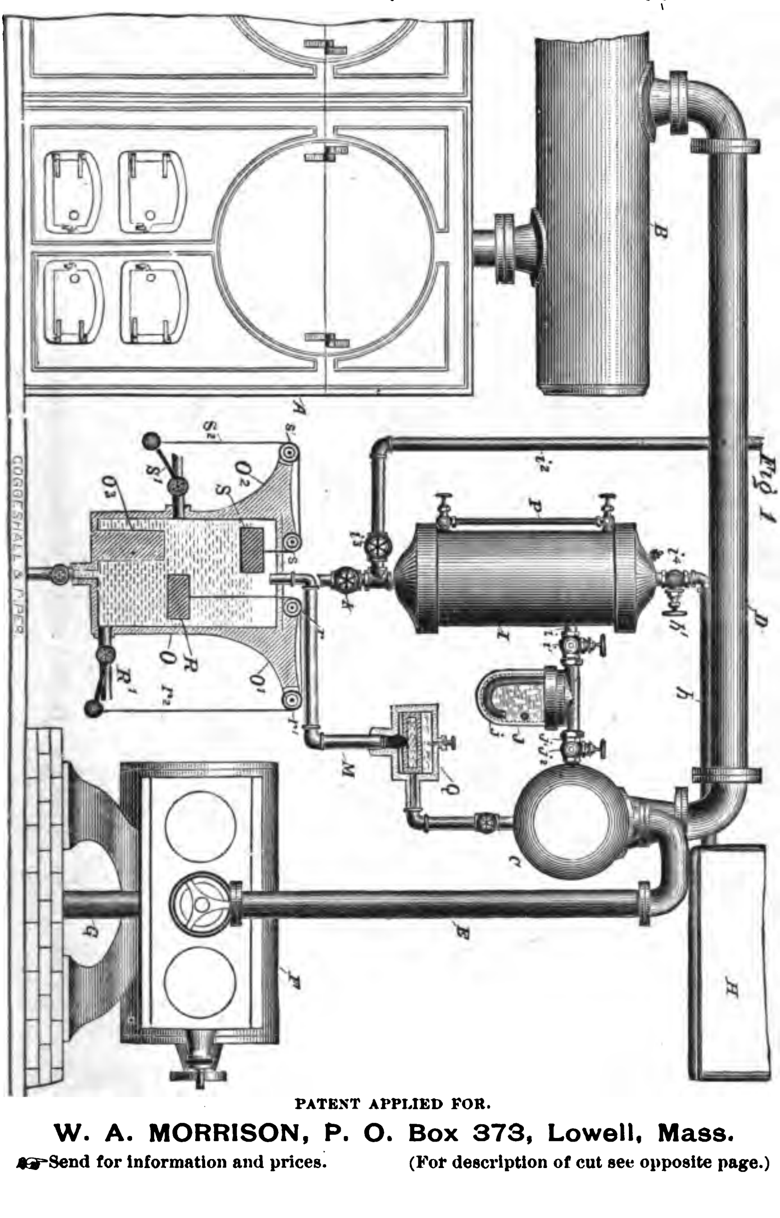

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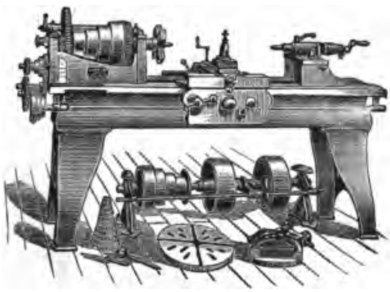

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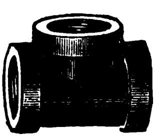

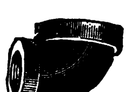

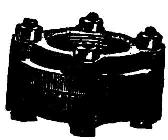

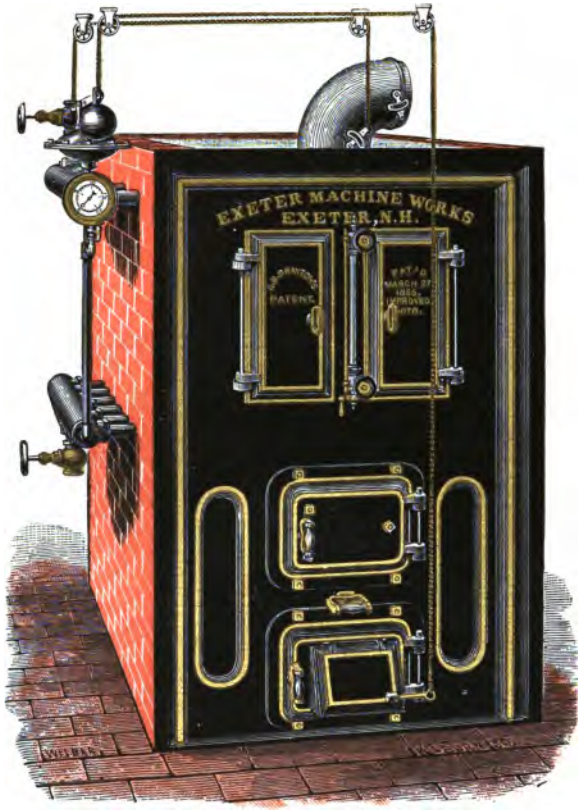

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WORKS, EXETER, N. H.

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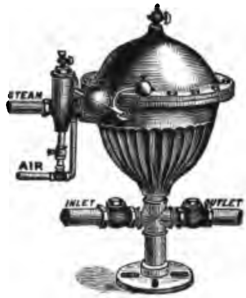

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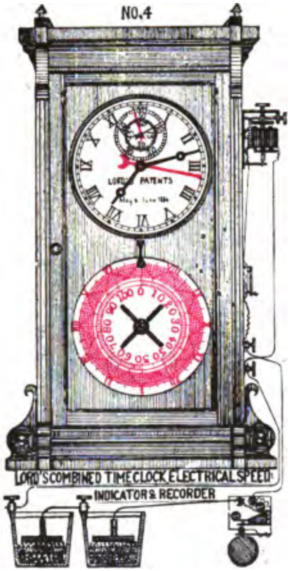

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